EXD.

IMP. INST. FOR AGRIC. LIBRARY
19 AUG 1935
SERIAL A. 60 B
SEPARATE

NCAG—AS.-5/2.

Vol. V, Part II

April, 1935

THE INDIAN JOURNAL OF AGRICULTURAL SCIENCE

Issued under the authority
of
The Imperial Council of Agricultural Research

Published for
THE IMPERIAL COUNCIL OF AGRICULTURAL RESEARCH

Annual subscription
Rs. 15 or 24s.
inclusive of Indian Postage

Price per part
Rs. 3 or 5s. 3d.
inclusive of Indian Postage

PUBLISHED BY MANAGER OF PUBLICATIONS, DELHI
PRINTED BY THE MANAGER, GOVERNMENT OF INDIA PRESS, NEW DELHI
1935

List of Agents in India from whom Government of India Publications are available.

(a) PROVINCIAL GOVERNMENT BOOK DEPOTS.

MADRAS:—Superintendent, Government Press, Mount Road, Madras.

BOMBAY:—Superintendent, Government Printing and Stationery, Queen's Road, Bombay.

SIND:—Library attached to the Office of the Commissioner in Sind, Karachi.

UNITED PROVINCES:—Superintendent, Government Press, Allahabad.

PUNJAB:—Superintendent, Government Printing, Punjab, Lahore.

BURMA:—Superintendent, Government Printing, Burma, Rangoon.

CENTRAL PROVINCES:—Superintendent, Government Printing, Central Provinces, Nagpur.

ASSAM:—Superintendent, Assam Secretariat Press, Shillong.

BIHAR AND ORISSA:—Superintendent, Government Printing, P. O. Gulzarbagh, Patna.

NORTH-WEST FRONTIER PROVINCE:—Manager, Government Printing and Stationery, Peshawar.

(b) PRIVATE BOOK-SELLERS.

Advani Brothers, P. O. Box 100, Cawnpore.
Aero Stores, Karachi.*
Albert Library, Dacca.
Banerjee & Bros. Ranchi, Messrs. G.
Banthiya & Co., Ltd., Kucheri Road, Ajmer.
Bengal Flying Club, Dum Dum Cantt.*
Bhawnani & Sons, New Delhi.
Book Company, Calcutta.
Booklover's Resort, Talkad, Trivandrum, South India.
Burma Book Club, Ltd., Rangoon.
Butterworth & Co. (India), Ltd., Calcutta.
Calcutta Book Agency, 16-1, Shama Charan Dey Street, Calcutta.
Chatterjee & Co., 3, Bacharam Chatterjee Lane, Calcutta.
Chukervertty, Chatterjee & Co., Ltd., 13, College Square, Calcutta.
City Book Co., Madras.
City Book House, Meston Road, Cawnpore.
Commercial Book Co., Lahore.
Das Gupta & Co., 54/3, College Street, Calcutta.
Deccan Book Stall, Poona 4.
Delhi and U. P. Flying Club, Ltd., Delhi.*
English Book Depot, Ferozepore.
English Book Depot, Taj Road, Agra, and Saddar Bazar, Jhansi.
English Book Depot, Bank Road, Ambala Cantonment, and Kasauli
English Bookstall, Karachi.
Faqir Chand Marwah, Peshawar Cantonment.
Gaya Prasad & Sons, Agra.
Grantha Mandir, Cuttack.
Higginbothams, Madras.
Hindu Library, 137/F, Balaram De Street, Calcutta.
Hyderabad Book Depot, Chaderghat, Hyderabad (Deccan).
Imperial Book Depot and Press, near Jama Masjid (Machhliwalan), Delhi.
Indian Army Book Depot, Dayalbagh, Agra.
Indian Army Book Depot, Jullundur City, and Daryaganj, Delhi.
Indian Book Shop, Benares City.
Indian School Supply Depot, 309, Bow Bazar St., Calcutta.
Insurance Publicity Co., Ltd., Lahore.
International Book Service, Poona 4.
Jaina & Bros., Mori Gate, Delhi, Messrs. J. M.
James Murray & Co., 12, Govt. Place, Calcutta (for Meteorological publications only).
Kali Charan & Co., Municipal Market, Calcutta.
Kamala Book Depot, 15, College Square, Calcutta.
Kamala Book Stores, Bankipore, Patna.
Karnataka Publishing House, Bangalore City.
Keale & Co., Karachi.
Krishnaswami & Co., Teppakulam P. O., Trichinopoly Fort, Messrs. S.
Lahiri & Co., Calcutta, Messrs. S. K.
Law Printing House, 11, Mount Road, Madras.
Law Publishing Co., Mylapore, Madras.
Lawrence and Mayo, Ltd., Bombay (for Meteorological publications only).
Local Self-Govt. Institute, Bombay.
London Book Co. (India), Arbab Road, Peshawar, Murree, Nowshera, Rawalpindi.
London Book Depot, B. I. Bazar, Bareilly, U. P.
Malhotra & Co., Quetta, Messrs. U. P.
Mohanlal Dossabhai Shah, Rajkot.
Nandkishore & Bros., Chowk, Benares City.
Nateson & Co., Publishers, George Town, Madras, Messrs. G. A.
New Book Co., "Kitab Mahal", 192, Hornby Road, Bombay.
Newman & Co., Ltd., Calcutta, Messrs. W.
North India Christian Tract and Book Society, 18, Clive Road, Allahabad.
Oriental Book Supplying Agency, 15, Shukrawar, Poona City.
Oxford Book and Stationery Company, Delhi, Lahore, Simla, Meerut and Calcutta.
Parikh & Co., Baroda, Messrs. B.
Pioneer Book Supply Co., 20, Shib Narayan Das Lane, Calcutta and 219, Cloth Market, Delhi.
Popular Book Depot, Grant Road, Bombay.
Punjab Religious Book Society, Lahore.
Punjab Sanskrit Book Depot, Saidmitha Street, Lahore.
Raghunath Prasad & Sons, Patna City.
Rama Krishna & Sons, Booksellers, Anarkali, Lahore.
Ram Krishna Bros., Opposite Bishrambag, Poona City.
Ram Narain Lal, Katra, Allahabad.
Ramesh Book Depot & Stationery Mart, Kashmere Gate, Delhi.
Ray & Sons, 43, K. & L. Edwardes Road, Rawalpindi, Murree and Peshawar, Messrs. J.
Ray Chowdhury & Co., 68/5, Ashutosh Mukherjee Road, Calcutta.
Rochouse & Sons, Madras.
Roy Chowdhury & Co., 11, College Square, Calcutta, Messrs. N. M.
Sampson William & Co., 127-B, The Mall, Cawnpur.
Sarcar & Sons, 15, College Square, Calcutta, Messrs. M. C.
Sarkar & Co., 2, Shama Charan De Street, Calcutta, Messrs. P. C.
Scientific Publishing Co., 9, Taltola Lane, Calcutta.
Seshachalam & Co., Masulipatam, Messrs. M.
Shivji & Co., P. O. Chaullaganj, Cuttack.
Shri Shankar Karnataka Pustaka Bhandara, Malamuddi, Dharwar.
S. P. Bookstall, 21, Budhwar, Poona.
Standard Bookstall, Karachi.
Standard Bookstall, Quetta.
Standard Book Depot, Lahore, Dalhousie and Delhi.
Standard Law Book Society, 5, Hastings Street, Calcutta.
Standard Literature Company, Ltd., Calcutta.
Students' Popular Depot, Kacheri Road, Lahore.
Surat and District Trading Society, Surat.
Taraporevala Sons & Co., Bombay, Messrs. D. B.
Thacker & Co., Ltd., Bombay.
Thacker, Spink & Co., Ltd., Calcutta and Simla.
Tripathi & Co., Booksellers, Princes Street, Kalbadevi Road, Bombay, Messrs. N. M.
Union Stores, Indore City.
University Book Agency, Kacheri Road, Lahore.
Upper India Publishing House, Ltd., Literature Palace, Ammuddaula Park, Lucknow.
Varadachary & Co., Madras, Messrs. P.
Wheeler & Co., Allahabad, Calcutta and Bombay Messrs. A. H.
Young Man & Co., Ajmer, and Egerton Road, Delhi.

*Agent for publications on Aviation only.

ORIGINAL ARTICLES

POLYEMBRYONY IN RICE (*ORYZA SATIVA*)*

BY

K. RAMIAH, M.Sc., Dip.Agri. (Cantab.), L.Ag.,
Paddy Specialist, Coimbatore,

N. PARTHASARATHY, B.A., B.Sc.Ag.,

AND

S. RAMANUJAM, B.A. (Hons.),
Assistants in Paddy

(Received for publication on 9th October 1934)
(With Plates VIII and IX)

CONTENTS

		Page
I.	Introduction	119
II.	Occurrence in rice	120
III.	Description of types	120
IV.	Discussion regarding origin and significance	121
V.	Summary	123
	References	124

I. Introduction

Polyembryony in angiosperms, though not so prevalent as in gymnosperms, is nevertheless of fairly general occurrence and has been known for a long time. The first discovery of this phenomenon is credited to Leeuwenhock, who as early as 1719 found two embryos in orange seeds. Since then, many more examples have been added to this, and to-day the cases on record are numerous. Among Gramineae this phenomenon, is rarer than in other flowering plants, and has been noticed in wheat, oats, rye [Hansen, 1920], *ragi—Eleusine coracana*—[Rangaswami Ayyangar and Krishnaswami, 1930] and sugarcane [Dutt and Subbarao, 1932]. As regards the origin and significance of polyembryony, diverse views are held and these will be briefly considered later, when the origin of this phenomenon in rice is discussed.

* Paper read at the Indian Science Congress, 1934.

II. Occurrence in rice

There are only three reported instances of polyembryony in rice. Komuro [1932] in Japan observed a rice seed, which upon germination produced two plumules. Rodrigo [1925] in Philippines found one seed of a rice variety producing two plumules and two primary radicles, on germination. He later germinated about 107,000 seeds of the variety and got only one seed with two plumules, and considered this phenomenon rare in rice. Jones [1928] in America obtained one seed from a cross between two rice varieties which produced two hybrid seedlings. The two plants were identical and he concluded that they arose from one fertilised egg. Considering the few and isolated instances of this phenomenon, it was believed to be of very rare occurrence in rice. At the Paddy Breeding Station, Coimbatore, however, quite a large number of cases of polyembryony have been observed and studied. Although seeds giving rise to two seedlings (Plate VIII, fig. 1*a*) were more common, some giving rise to triplets (Plate VIII, fig. 1*b*) were also observed.

In the course of examination of the seed beds of F_3s of a cross between two varieties, T. 24 and T. 381, one seed with two seedlings (Plate VIII, fig. 2*a*) each with its coleoptile and primary root was observed in one of the seed beds. Further search for similar cases resulted in the isolation of five more twins, one of them being composed of two lethal albinos (Plate VIII, 2*b*) the latter having been found in a family segregating for albinism. The occurrence of this phenomenon in the hybrid progenies led to the idea of examining the parent varieties for the presence of this character. A large number of seeds in each of the two parent varieties was germinated until the plumule and the radicle had emerged to more than an inch and these were examined individually for polyembryony. It was found that one of the parents, a pure line, T. 24, showed this phenomenon consistently in the proportion of 1 in 1,000 seeds (Plate IX, fig. 1). Out of several cases isolated, the majority was found to be of twos, while a few were triplets. A similar search in the other parent and some other varieties, however, did not reveal this phenomenon. It may be mentioned in this connection, that the regular occurrence of this phenomenon in T. 24 probably has some significance. Some hereditary tendency apparently exists for this particular feature in this strain and this character is exhibited in the hybrid progenies, (F_1s, F_2s and F_3s), wherever this pure line has been one of the parents. It is not to be supposed, however, that this phenomenon does not occur in other cross progenies, as occasionally double embryos were also obtained from some crosses where T. 24 was not involved as a parent.

III. Description of cases

The several cases of polyembryony isolated from the pure line, T. 24, and the various hybrid progenies may be classified under two heads :—

(*i*) Genetically identical, and

(*ii*) Genetically different.

FIG. 1.

a, A seed with two seedlings. *b*. A seed with three seedlings.

FIG. 2.

a. A green twin. *b*. An albino twin.

FIG. 1.—Germinated seeds showing polyembryony.

FIG. 2—An albino and a green seedling from a single seed.

1. Genetically identical cases

(*a*) *From the pure line.*—Several twins and a few triplets isolated from the pure line T. 24, were separated and grown to maturity. The individuals constituting the twin or triplet are easily separated after about 10 days' growth in the nursery, when the absorption of the endosperm is complete. All the twins except in one case were found identical in their genetic constitution, vigour of growth, etc., and resembled the parent. Among the triplets, one was always slightly less vigorous than the other two, although all of them were of the same genetic constitution.

(*b*) *From hybrid progenies.*—A number of cases of identical twins were met with in F_1, F_2 and F_3 progenies of crosses between T. 24 and other varieties. Two cases of identical twins were also observed in other hybrid progenies, where T. 24 was not concerned. Among the identical twins, two instances of twin albinos also were met with which, as would be expected, died out early.

2. Genetically different cases

(*a*) *From the pure line.*—By far the most interesting case of polyembryony noted in the pure line is the appearance of a normal diploid individual in association with a haploid from one seed. A description of the haploid is given in a separate publication. [Ramiah, Parthasarathy and Ramanujam ; 1933.]

(*b*) *From hybrid progenies.*—In one of the F_3 families of a cross between two varieties, which was showing a mono-factorial segregation for normal green and albino seedlings, one seed was found to give rise to a normal green and a lethal albino (Plate IX, fig. 2). This association in a single seed is very interesting, as the breeding behaviour of the normal green partner, the albino seedling having died out early, throws some light on the origin of polyembryony in rice. When the green seedling was grown to maturity and the seeds from this plant were sown again, it was found that the progeny consisted entirely of green seedlings, thus showing its homozygous nature with respect to the chlorophyll factor.

IV. Discussion regarding origin and significance

Polyembryony in angiosperms has been observed to arise mostly due to the development of embryos apogamously from cells inside the embryo-sac or from the nucellus and integument by sporophytic budding. Cases where this phenomenon has resulted from the development of distinct embryo-sacs are also recorded and these are classified under pseudo-polyembryony by Ernst [1901] and quoted as such by Coulter and Chamberlain [1903]. The list furnished by Coulter and Chamberlain is fairly exhaustive and shows the diverse sources of origin of this phenomenon in angiosperms. While this feature is rare in certain species, it appears to be the normal method of seed formation in some and is regularly found in certain others, notably in the mango and some of the citrus. Its appearance in several

distinct groups and its origin by several distinct methods from different morphological sources have given rise to diverse views regarding its significance.

As regards the source of polyembryony in rice, the occurrence and breeding behaviour of the green-albino twin, already referred to, throws some light. It uggests that two embryo-sacs of different factorial constitutions are concerned in heir development. If we designate **G** as the factor for green colour and **g** for its allelomorph, then the heterozygous plant giving rise to the polyembryonic seed will be **Gg** and the twins themselves **GG**(homozygous green) and **gg**(homozygous albino). It is obvious that the sporophytic tissue of the seed, being itself heterozygous, cannot give rise to homozygous individuals of the constitutions **GG** and **gg** and that the twins should have arisen only from the gametophyte. At gametogenesis, the heterozygous plant would give rise to pollen and embryo-sac mother cells with either the factor **G** or its allelomorph **g** in each. If in this case, as is usual, only one embryo-sac mother cell develops, it can contain only either the factor **G** or its allelomorph **g** and such an embryo-sac cannot give rise to two homozygous individuals of the constitutions **GG** and **gg**. In an embryo-sac containing **G**, the possible embryos that can develop are **GG** and **Gg** by fertilization and **GG** by apogamy. In an embryo-sac with **g**, the possible embryos are **gg** and **Gg** by fertilization and **gg** by apogamy. From the above it is clear that any one embryo-sac cannot give rise to the twins with the constitutions **GG** and **gg** and it is necessary for two embryo-sacs to be formed with different factorial constitutions, for such a phenomenon as a homozygous green and an albino seedlings to develop from the same seed. Such a condition, where more than one embryo-sac has developed in one ovule is not rare in the history of development of the female gametophyte in angiosperms. Coulter and Chamberlain cite a number of examples where more than one embryo-sac has been found to develop. Recently Banerji and Bhaduri [1933] report the presence of two separate embryo-sacs with two well developed embryos in the same ovule of *Nicotiana plumbaginifolia*. Even in rice, a case of two embryo-sac mother cells in one ovule has been observed and figured by Kuwada [1910]. Hence, besides other forms of polyembryony, like nucellar embryony, etc., which may exist in rice, that developing from two embryo-sacs is also a possible source of this phenomenon. Detailed embryological studies are underway to confirm this observation.

Regarding the significance of polyembryony in general, several views are held as already stated. Until a more thorough knowledge of this phenomenon is gained no definite statements on this point would be justified as all such could at best be only suggestions. Strasburger [1877, cited by Tiwary] considered it as a gradual change from the normal formation of the sexually produced embryo, as the result of weakening of sexuality, of pollen formation and of the capacity of the embryo to develop. Pfeffer [1897, cited by Tiwary] has suggested that it is merely a form of budding, the conditions in the embryo-sac giving it the form of the sexually produced embryo. Ganong [1898] on the other hand suggests that it may be the

early stages in the development of some thing new. In its origin in several distinct groups " it is comparable with the appearance of heterospory, but whether polyembryony like heterospory will lead to some higher condition remains to be seen, though we shall not see it." Echinger [1910, cited by Tiwary] believed it to be an attempt on the part of the plant to increase its capacity for dispersal. Ernst [1918, cited by Tiwary] does not subscribe to any of these views but maintains that it is the outcome of the hybrid nature of the plants that exhibit it, and is a form of apospory. He holds that hybridisation is the initial cause of parthenogenesis, apospory, apogamy, nucellar embryony and polyembryony. Chauveaud [1892, cited by Coulter and Chamberlain] considers that polyembryony is a primitive feature of angiosperms, the number having got reduced in the interest of a strong embryo. He found in *Vincetoxiam nigrum* and *V. medium*, polyembryony being a regular feature and also noted four or five bodies in the pollen tube which he thought might be interpreted as male nuclei being responsible for the phenomenon. Dutt and Krishnaswami [1932] have recently found more than two male nuclei in the pollen tube of sugarcane, which may be capable of effecting additional fertilisations and causing polyembryony. Dodel [1891, cited by Coulter and Chamberlain] in describing synergid fertilisation in *Iris siberica* implies somewhat a similar view with that of Chauveaud regarding the significance of polyembryony. Recently Kappert [1933] in an elaborate study of polyembryony in flax consisting of a detailed analysis of different crosses concludes, that polyembryony is a recessive character probably conditioned by a series of multiple allelomorphs. He suggests that in hybridisation, suitable recombination of the recessive multiple factors from various strains occurs, as a consequence of which polyembryony segregates out in certain lines. Our recent observations in the F_4 progenies of a cross between T. 24 and T. 260 have shown several families exhibiting this phenomenon in large numbers. This fact coupled with the occurrence of this phenomenon in T. 24 with a regularity, amounting almost to a hereditary tendency is suggestive of this feature being a heritable character in rice. A detailed analysis of the several cross progenies in which this character is found to segregate is underway and it is expected will throw light on this point.

V. Summary

1. Polyembryony which is believed to be a rare phenomenon in rice, was observed to occur in fairly large numbers at the Paddy Breeding Station, Coimbatore, in a pure line T. 24 and in several hybrid progenies, the pure line alone exhibiting the feature consistently in the proportion of 1 in 1,000 seeds. Although seeds giving rise to two seedlings were more common, some giving rise to triplets, which is being recorded for the first time in rice, were also observed.

2. The several cases of polyembryony isolated were classified and described. Among genetically identical twins, besides the normal green, some lethal albino twins were also observed. Genetically different twins included cases where a haploid was found in association with a diploid and a green seedling with an albino.

3. The occurrence and breeding behaviour of some of the twins are discussed in relation to the origin of polyembryony in rice, and it is tentatively suggested subject to confirmation by further embryological studies in progress, that the development of more than one embryo-sac might also contribute to the origin of this phenomenon. As regards its significance, which is being investigated in more detail, evidences are available which show it to be a hereditary character.

REFERENCES

Bannerji, I. and Bhaduri, P. N. (1933). *Current Sci.* **1,** 310-311.

Coulter, Y. M. and Chamberlain, C. J. (1903). "Morphology of Angiosperms", New York.

Dutt, N. L. and Krishnaswami, M. K. (1932). *Ind. J. Agric. Sci.* **2,** 47-49.

Dutt, N. L. and Subbarao, K. S. (1933). *Ind. J. Agric. Sci.* **3,** 37-53.

Ganong, W. F. (1898). *Bot. Gaz.* **25,** 221-228.

Hansen, W. (1921). *Abs. in Expt. Stat. Rec.* **45,** 533.

Jones, J. W. (1928). *J. Amer. Soc. Agron.* **20,** 533.

Kappert, H. (1933). *Plant Breeding Abs.* **4,** No. 1, item 201.

Komuro, H. (1922). *Bot. Mag. Tokyo* **36,** 23-24.

Kuwada, Z. (1910). *Bot. Mag. Tokyo.* **24,** 267-281.

Ramiah, K., Parthasarathy, N. and Ramanujam, S. (1933). *Current Sci.* **1,** 277-278.

Rangaswami Ayyangar, G. N., and Krishnawswami, N. (1930). *Mad. Agric. J.* **18,** 393-95.

Rodrigo, P. (1925). *Philip. Agric.* **14,** 629-630.

Tiwary, N. K. (1926). *J. Ind. Bot. Soc.* **5,** 124-136.

POLLINATION STUDIES IN *TORIA* (*BRASSICA NAPUS* L. VAR. *DICHOTOMA*, PRAIN) AND *SARSON* (*BRASSICA CAMPESTRIS* L. VAR. *SARSON*, PRAIN)*

BY

ALI MOHAMMAD, M.Sc. (AGRI.), L.AG.,

Botanist for Oilseeds, Punjab Agricultural College, Lyallpur

(Received for publication on 18th January 1935)

CONTENTS

I. IMPORTANCE OF *TORIA* AND *SARSON* AS OILSEED CROPS IN THE PUNJAB 126

II. IMPORTANCE OF STUDYING MODES OF POLLINATION . . 126

III. REVIEW OF PAST WORK 127

IV. OBSERVATIONS AND RESULTS 128

(*A*) *Toria* 128

(*a*) Floral mechanism and pollination . . . 128

(*b*) Insects and pollination 128

(*B*) *Sarson* 131

Floral mechanism and mode of pollination . . 131

(*C*) Self and cross-fertilization in *toria* and *sarson* . . 132

(*D*) Effect of self-pollination treatment at different stages of flower development on pod and seed setting . 140

(*E*) Duration of the period of receptivity of stigma and viability of pollen grains 142

V. BREEDING OF IMPROVED VARIETIES OF *TORIA* AND *SARSON* . 148

(*A*) Evolution of unit species 148

(*B*) Mass selection and the factors concerned . . . 148

(*C*) Hybridization 151

VI. SUMMARY 152

REFERENCES 154

* The original paper with a few more details was submitted to the Pubjab University for the degree of M.Sc. (Ag.) and was accepted.

I. Importance of *toria* and *sarson* as oilseed crops in the Punjab

Toria and *sarson* for which the botanical names *Brassica napus* L. var. *dichotoma* Prain, and *Brassica campestris* L. var. *sarson* Prain, have been used in this paper on the authority of Prain [1898], are by far the most important oilseed crops of the Punjab. *Toria* is chiefly grown in the canal colonies and on the average of five years ending 1932-33 occupied an area of 554,892 acres annually of which 487,881 acres were irrigated. *Sarson* is sown almost all over the province except in some of the hills. The area under this crop is not recorded separately in the official records but is given with *taramira* (*Eruca sativa*) and *rai* (*Brassica juncea*). The total area under these three crops based on the average of five years ending 1932-33 was 643,378 acres each year out of which 93,519 acres were irrigated. The fact that *sarson* is generally grown mixed with gram, barley, or wheat, and rarely alone makes the exact determination of the area under this crop rather difficult, but from a rough estimate of its acreage in various districts, supplied by the revenue authorities concerned, it appears that *sarson* constitutes about 30 per cent of the area recorded under these three crops jointly.

Toria seldom succeeds without irrigation and is more liable to suffer from cold and frost. It is, therefore, usually sown earlier than other *Rabi* (winter) oilseed crops and is treated as *zaid Kharif* (autumn crop). It is generally sown in September and is harvested in December-January.

Sarson is usually sown in October-November almost entirely on unirrigated areas and is harvested in February-March. When sown mixed with other crops the seed is dropped in furrows made by a plough at intervals of four or five feet.

Besides extraction of oil from its seed, *sarson* crop is also used largely as fodder and vegetable. *Toria*, on the other hand, is grown almost entirely for the extraction of oil from its seed. Its importance lies chiefly in the fact that its produce is available, for sale, to the farmer at the time when he needs money for paying off land revenue.

II. Importance of studying modes of pollination

From the plant breeder's point of view the methods employed for the improvement of a crop depend, to a large extent, on the mode of pollination of the crop concerned. A study of pollination methods is extremely necessary, as, in light of these studies the right lines of effecting improvement in a crop can be decided upon and adopted, thus avoiding considerable waste of time and labour. The embryo, which gives rise to an adult plant, results from the fusion of two (male and female) gametes or reproductive cells, the constitution of which may be identical or different. In case these two gametes have, habitually, the same constitution that is to say, the plant is "self-fertilized" from generation to generation, "the like will produce like". The main process of bringing about improvement

in such crop plants is, in principle, a simple one. It consists in selecting, from the local material, a large number of plants differing from one another, multiplying their seed, subjecting them to suitable trials, and then choosing from amongst them, for introduction into general cultivation, one or more which turn out to be most suitable for the conditions prevailing in the locality concerned. Even if there be an occasional variation from this mode of pollination, this method is still applicable. On the other hand, if the two gametes fusing together are always different in constitution or frequently so, that is, a large amount of cross-fertilization occurs in the plant, one generation must be different from the other. In such cases the evolution of unit species and keeping them constant from year to year would be extremely difficult and almost impossible in practice, and from the further fact that almost all such unit species are known to be less vigorous than the naturally occurring heterozygous material the evolution of such unit species would not appear, from the economic standpoint, to be of primary importance. In such crops some type of group-breeding would appear to be the more practical and easier method for effecting improvement.

III. Review of past work

So far as the two crops under consideration, *viz.*, *toria* and *sarson*, are concerned little work appears to have been done in studying their modes of pollination. Some excellent work appears to have been done on the fertility of the genus Brassica in Europe. But *toria* and *sarson* are not the commercial crops of Europe and it is also known that in this genus of plants there exists a wide variation in fertility from species to species and even between varieties within one and the same species, therefore, the work done in Europe does not exactly bear on the subject matter contained in this paper. Even in India, where these two crops are commercially important, there is not much reference available pertaining to this subject, except some preliminary investigations conducted by Howard, Howard and Rahman Khan [1910]; they say that "*Sarson* readily sets seed under bag and a certain amount of self-fertilization is therefore to be expected in free flowering plants". In *toria*, they say, setting under bag is not so easy as in *rai* and *taramira*. Work on *toria* and *sarson* in the Punjab was originally started in the year 1910 by Mr. Milne, C.I.E., then Economic Botanist to Government, Punjab. He collected a number of local varieties of these crops for study. The observations made by him and the author of this paper who worked with him for several years since 1913 showed that considerable crossing occurred in the field in these two crops and that it was very difficult to keep the various varieties pure. No detailed investigations as recorded in this paper were, however, then undertaken. Systematic work on these crops was started in 1926 and developed further in 1929 since when the author of this paper took independent charge of the work on oilseed crops in the Province. The results of some of the breeding investigations on these crops were published [1931] by the author jointly with R. D. Singh and Zafar Alam and it

had been shown that in both these crops, *viz.*, *toria* and *sarson*, the floral mechanism is such that it provides few chances for natural selfing. Under bags they are shy seed setters, the production of normal seeds under bag being about 1/46th and 1/27th respectively, of that in free-flowering branches open to the visits of insects. The yellow seeded form of *sarson* was, however, found to be an exception to this, as it gave quite a good setting under bag. The investigations carried out by the author at Lyallpur in recent years have added greatly to the results obtained previously. The present paper is an attempt to record the important findings up-to-date and it is hoped that it will prove to be a useful contribution towards the elucidation of some of the breeding problems connected with these crops.

IV. Observations and results

(*A*) *Toria*

(*a*) *Floral mechanism and pollination.*—Examination of flowers shows that in the bud-stage immature stamens lie below the stigma with their pollen-liberating sides directed towards the style. As the flower opens, the filaments of the four long stamens increase in length and carry the anthers above the stigma. At the same time these anthers turn half-way round so that their dehiscing surfaces are turned away from the stigma even after the flower has opened ; but their anthers remain much below the stigmatic surface. The mechanism is, therefore, not greatly in favour of self-pollination. Each flower has four nectaries. Nectar is profusely secreted by each of the two nectaries situated at the bases of the two short stamens. The other two nectaries which are situated at the bases of the long stamens do not appear to be functional.

The flowers usually open between 8-30 to 10-30 a.m. and as the flowers open the anthers also begin to dehisce from the apex downwards. The dehiscence is usually complete by 12 noon. The flower remains fully open for a day and then it gradually begins to wither and on the fourth or fifth day, after opening, the sepals, petals, and stamens are shed. By this time the fertilized ovary also increases in length.

(*b*) *Insects and pollination.*—The full significance of researches in connection with insects as pollinating agents seems to have been realized only in comparatively recent years. Lewis and Vincent [1909], Chittenden [1914], Morris [1921], Hooper [1922-23], Pammel [1923] and Hutson [1925-26] have definitely established the necessity of honey-bees for the successful pollination of fruit trees like apples, pears, peaches and plums, while Fox Wilson [1929] gives a detailed account of the different species of insects concerned in the pollination of hardy fruits. Insect visits to fruit blossoms greatly increase the percentage of fruit setting and thus materially increase the output. Hendrickson [1916], Overholser [1927] and Farrar [1931], therefore, suggest supplementing of wild insect pollinizers by means of hive-bees. The demand for honey-bees to effect cross-fertilization at the blooming period is steadily increasing in America and according to Phillips [1930] will still

further increase. He, therefore, emphasises that "the requirements for colony strength in order to have bees which will give good service in pollination of fruit" should be thoroughly investigated.

Out of the agricultural crops insect visitors of red clover (*Trifolium partense* L.) seem to have been more extensively studied. Williams [1925] has given an admirable historical resume of the work done in this connection from 1876 to 1925 in different parts of the world. He, and more recently Walton [1927] have established that humble-bees (*Bombus sp.*) are the most important for red clover pollination.

Balls and others [1929] have shown that solitary and ground bees are much more important agents in the natural crossing of cotton flowers in Egypt and consequent varietal deterioration than the honey-bees. Treherne [1923] shows that honey-bees are the most important for seed production in vegetable crops.

In India, the problem of studying insect visitors of farm crops lies practically untouched. Burkill [1906, 1, 2, 3 ; 1907 ; 1908 ; 1911] published a series of notes on the pollination of flowers in India and contributed an article on "Insects and flowers" in Indian Insect Life [Lefroy, 1909, pp. 222-223]. In these contributions Burkill records the names of insect visitors of different kinds of flowers.

The study on the insect visitors of *toria* and *sarson* at Lyallpur with particular reference to the part played by them in the pollination of these crops, was taken up by the author in 1929, when representatives of three orders, *viz.*, Hymenoptera, Lepidoptera, and Diptera were noticed to visit *toria* and *sarson* flowers at Lyallpur. The detailed observations were recorded in later years with the help of Mr. Khan A. Rahman, Assistant Professor of Entomology who kindly helped in the collection and identification, etc., of the insects concerned. One hundred and seventeen different species of insects falling under the following 7 orders (given in order of importance) have been recorded visiting *toria* flowers :—

1. Hymenoptera.
2. Diptera.
3. Lepidoptera.
4. Coleoptera.
5. Rhynchota.
6. Thysanoptera.
7. Neuroptera.

Observations made on the relative abundance of the various species of insects and their relative efficiency in affecting pollination of *toria* showed that *Andrena ilerda* (Hymenoptera) is by far the most important and efficient pollinator of *toria*, and that the female is much more active and useful than the male in the pollination work. Next to *Andrena ilerda* in importance are *Apis florea* (Hymenoptera) and *Halictus sp.* (Hymenoptera). The rest of the insects do not appear to be so useful either because they are met with only in small numbers or because they are indifferent workers ; while a few are predators, *e.g.*, *Philanthus depraedator* Smith

and *Liris haemorrhoidatis* F. (Hymenoptera), and therefore, they do more harm than good by killing the useful pollinating insects. Considered from all points of view, *Andrena ilerda*, *Apis florea* and *Halictus sp.* may be regarded as the chief pollinating agents of *toria* as these insects abound in numbers during the main flowering season of *toria* and furthermore are very ardent and persistent workers. Between them these three insects have been recorded to make up on the average about 82 per cent of the insect visitors to *toria* flowers as follows :—*Andrena ilerda* 54 per cent, *Apis florea* 19 per cent, *Halictus sp.* 9 per cent.

As already pointed out above, the floral mechanism in *toria* is such as to reduce the chances for self-pollination to the minimum. Therefore, the flowers must depend on some external agency for bringing about pollination. Observations made in this connection show that insects play a great part in the pollination and that wind hardly plays any role, if at all, in this respect. The insects start visiting the flowers at 10 a.m. and are met with in largest numbers between 12 noon and 2 p.m. After 3 p.m. their number decreases considerably, so much so that after 4 p.m. hardly any insect can be seen visiting the flowers. Insects visit only freshly opened flowers for the collection of the nectar, which is secreted by the nectaries only on the day the flower opens. It is interesting to note that an examination of the anthers of freshly opened flowers at about 3 p.m. shows them to be absolutely devoid of their pollen which is evidently carried away by insect visitors.

Detailed observations were recorded during the year 1929-30 with regard to the frequency of insect visits to flowers. For this purpose, a number of individual flowers and inflorescences were earmarked at different places in the field and the number of insects visiting them per hour was recorded for about a fortnight from 9 a.m. to 5 p.m. daily. The results show that, on the average, an inflorescence and a flower were visited by insects 71 and 26 times respectively per day. The frequency of insect visits is so great that there is absolutely no chance for a flower to escape pollination through the agency of insects. It may, however, be pointed out that the activity of insects is largely controlled by weather. It has been ascertained that very few insects come out to visit flowers on cloudy days and the few that do come out remain lethargic. A comparison of the number of hourly visits by insects to an individual inflorescence on a cloudy and a clear day is given below :—

Comparison of frequency of insect visits on a clear and a cloudy day

Kind of weather	Number of insect visitors between								
	9 & 10 a.m.	10 & 11 a.m.	11 & 12 a.m.	12 a.m. & 1 p.m.	1 & 2 p.m.	2 & 3 p.m.	3 & 4 p.m.	4 & 5 p.m.	Total
Clear day . .	..	13	20	29	42	28	21	..	153
Cloudy day . .	..	..	1	..	..	2	..	..	3

It is apparent from the above that the number of insects visiting the flowers on a clear day is far greater than those visiting the flowers on a cloudy day Naturally, therefore, whatever setting occurs on cloudy days takes place from natural self-pollination, the extent of which in this crop, as will be shown later, is very little. From these facts it follows that the intervention of long spells of cloudy, humid, or rainy weather during the flowering period of *toria* would decrease the percentage of setting. It has actually been observed that the flowers opening on a cloudy, humid day do not set into pods, with the result that, if such weather lasts sufficiently long, considerable podless gaps appear on the fruiting branches.

It may also be noted that, unlike cotton pollen, *toria*, and *sarson* pollen grains do not burst on coming into contact with free water and that the flowers crossed artificially on a cloudy day set into normal pods. Therefore, the only possible explanation is that the reduction in setting with the intervention of cloudy, humid and rainy weather is simply the result of a reduction in the visits of pollinating insects.

(*B*) *Sarson*

Floral mechanism and mode of pollination.—The floral mechanism in all brown seeded forms of *sarson*, that have been under observation so far, is the same as in *oria*, and hence the chances for natural self-fertilization are few. But one form of *sarson*, which is yellow-seeded and is grown to a limited extent in some parts of the North Western district of the Province, has been found to differ in this respect. In this case, the pollen-liberating sides of the anthers of the long stamens remain towards the stigma even in a fully opened flower. These anthers at the time of dehiscence meet over the stigma and then begin to turn away from the stigmatic surface, each forming a sort of coil. A little before, or during this process, some pollen drops on the stigma so that a good amount of self-fertilization can be expected. The anthers of the short stamens do not, however, reach the stigma and, therefore, do not appear to take any part in the process of self-pollination. As reagrds the mode of pollination, varieties of all *sarson* with the exception of this particular form, have been found to behave in the same manner as *toria*. Generally speaking, the same species of insects which visit *toria* flowers have been found to visit *sarson* flowers also with the only difference that their relative abundance in the case of *sarson* crop is not usually the same as that found in the case of *toria* crop. For example, in *toria* crop, *Andrena ilerda* occupied the premier place, but in the case of *sarson* where this insect is by no means an inappreciable agent in pollination work, *Apis florea* is met with in such large numbers and is such a persistent worker that it should be regarded as the most important pollinating agent of *sarson*. The main flowering season of *sarson* crop usually comes about $1\frac{1}{2}$ to 2 months later than that of *toria* and it is very likely that during this interval *Apis florea* finds more favourable conditions and consequently its population increases. Further researches in this direction are being conducted in collaboration with the Entomological Section.

(*C*) *Self and cross-fertilization in* toria *and* sarson

In order to explore the possibilities of the isolation of pure lines in *toria* and *sarson*, attempts were made to secure their self-fertilized seed by enclosing plants in muslin bags. It was repeatedly observed that in these two crops, except in the yellow seeded form already referred to above, little setting resulted, and consequently a sufficient supply of seed from a single plant could not be obtained. Percentage setting under bag was determined in each of the years 1926-27 to 1931-32 (Table I).

TABLE I

Result of setting under bag in toria *and* sarson *for the years 1926-27 to 1931-32*

Year	Toria			Sarson					
				Brown seeded			Yellow seeded		
	No. of flowers bagged	No. of pods set	Percentage of setting	No. of flowers bagged	No. of pods set	Percentage of setting	No. of flowers bagged	No. of pods set	Percentage of setting
1926-27 . .	3,328	282	8·4	10,855	1,773	16·3	38	38	100
1927-28 . .	7,357	1,147	15·5	606	185	30·5	162	135	83·3
1928-29 . .	8,052	677	8·4	1,137	263	23·1	...	...	...
1929-30 . .	1,019	277	27·1	3,614	1,047	28·9	...	...	...
1930-31 . .	2,201	203	9·2	2,714	595	22·3	45	44	97·8
1931-32 . .	1,238	266	21·4	3,200	628	19·6	189	178	94·2
Total or average	23,195	2,852	12·3	22,126	4,491	20·3	434	395	91·0

From these figures it will be seen that on the average of six years there is a pod-setting under bag 12·3 per cent and 20·3 per cent respectively in *toria* and brown-seeded *sarson*. It may be pointed out, however, that the actual seed formation is very much less than what the figures of pod setting show because the pods, which succeed in setting inside bags, contain very much fewer seeds than the pods formed on free-flowering plants.

With a view to determine whether the very poor setting obtained under bag was entirely due to the floral mechanism providing few chances for pollination or to some other causes also, and also to find out if with the aid of artificial self-pollination self-fertilized seed from individual plants could be had in quantities sufficient to permit the isolation of pure lines, certain experiments were carried out on a number of *toria* plants in the year 1927-28. For this purpose many plants were

selected and different branches of the same plant were accorded one of the following three treatments :—

(*a*) One branch was left free-flowering, *i.e.*, open to the visits of insects.

(*b*) One branch was bagged but otherwise left untouched, and

(*c*) One branch was bagged but freshly opened flowers were each day self-pollinated by means of a camel hair brush. The results so obtained (Table II) show that on the average, for every 100 flowers treated, artificial selfing by means of hand-pollination increased the amount of both pod-setting and seed production from 14·5 and 27 to 33·6 and 90 respectively. But these figures are far less than those obtained from free-flowering branches, in which case 60 pods and 1,086 seeds were formed per 100 flowers. It will also be seen that although artificial selfing appreciably increased the pod-setting, yet there was very little increase in the seed production per pod, as compared to those obtained in free-flowering branches. This shows that pod-formation and seed-formation in *toria* were, in these experiments, largely independent of each other. This is in accordance with the results obtained by Nelson [1927] in some selfing experiments with some other forms of the genus *Brassica*.

TABLE II

Comparison of setting in free-flowering, artificially selfed, and naturally selfed flowers in toria *in the year 1927-28*

Plant No.	Bagged						Bagged but artificially selfed (Hand-pollinated)						Free-flowering					
	Total No. of flowers under observation	Total No. of pods formed	Percentage of pod-setting	Average No. of normal seeds per pod	Total number of normal seeds	Average number of normal seeds calculated per 100 flowers treated	Total number of flowers treated	Total number of pods formed	Percentage of pod-setting	Average number of normal seeds per pod	Total number of normal seeds	Average number of normal seeds calculated per 100 flowers	Total number of flowers under observation	Total number of pods formed	Percentage of pod-setting	Average number of normal seeds per pod	Total number of normal seeds	Number of normal seeds formed per 100 flowers
1 . .	289	123	42·6	2·62	322	...	41	37	90·2	4·36	161	...	62	50	80·6	22·18	1,109	...
2 . .	679	93	13·7	1·40	130	...	51	36	70·6	2·58	93	...	102	63	61·8	17·90	1,127	...
3 . .	151	23	15·2	1·05	24	...	42	20	47·6	1·10	22	...	42	25	59·5	16·52	413	...
4 . .	222	1	0·4	0·00	0	...	86	6	7·0	0·50	3	...	44	20	45·0	10·15	203	...
5 . .	253	16	6·3	1·37	22	...	32	5	15·6	1·20	6	...	57	40	70·2	11·02	441	...
6 . .	266	24	9·0	1·14	27	...	42	2	4·8	1·00	2	...	85	70	82·3	18·23	1,276	...
7 . .	137	10	7·3	1·70	17	27	30	3	10·0	1·66	5	90	80	45	56·2	12·33	555	1,086
Average .	...	...	14·5	...	...	27	...	...	33·6	...	...	90	...	...	66·0	...	...	1,086

In these experiments some damage due to handling or some other cause occurred to flowers, and such damaged flowers have been included in the class of failures. Even if these damaged flowers are excluded from the above results, the average number of normal seeds per 100 flowers in the case of the different treatments would be as follows :—

Treatment	No. of seeds per 100 flowers
Bagged flowers	40
Artificially selfed flowers	186
Unbagged flowers	1,269

These figures, though slightly different, are of the same order as the previous ones and lead to the conclusion that in freshly opened flowers of *toria* even self-pollination by hand does not produce an appreciable amount of seed.

In order to see whether the poor setting under bag, with or without artificial selfing, was in some way due to the effect of bags used for enclosing the branches, experiments were arranged to compare the following three treatments :—

(*a*) Flowers were bagged only.

(*b*) Flowers (freshly opened) under bag were artificially selfed by hand.

(*c*) Flowers (freshly opened) under bag were crossed with pollen from other *toria* plants.

In each set of these experiments the three different treatments were given to three different flowering branches on each plant and the muslin bags used were in all cases of exactly the same type and material. The results obtained (Table III) show that artificially crossed flowers under bag give an excellent setting, immensely greater than in the cases where setting depended on selfing alone, natural or artificial. It will again be seen that while artificial selfing appreciably increased pod-setting, it made no increase in the production per pod of normal seeds. Crossing under bag gives, not only, an immense improvement in setting, but the pods formed are also much bigger and better developed (Table V). From Table V it will be seen that ' selfed ' pods have about half the length of ' crossed ' pods and that the loss in length which results from selfing is mainly confined to the seed-bearing portion of the pod.

TABLE III

Comparison of setting in toria *under bag in untouched, artificially selfed, and crossed flowers in the year 1929-30*

Plant No.	Untouched						Artificially selfed (Hand-pollinated)						Crossed					
	Total number of flowers under observation	Total number of pods formed	Percentage of pod setting	Average number of normal seeds per pod	Total number of normal seeds	Number of normal seeds formed per 100 flowers	Total number of flowers treated	Total number of pods formed	Percentage of pod setting	Average number of normal seeds per pod	Total number of normal seeds	Average number of normal seeds calculated per 100 flowers	Total number of flowers treated	Total number of pods formed	Percentage of pod setting	Average number of normal seeds per pod	Total number of normal seeds	Average number of normal seeds calculated per 100 flowers
1 . .	85	47	55·3	2·3	107	...	68	54	79·4	2·4	131	...	50	50	100·0	22·3	1,114	...
2 . .	45	11	24·4	1·0	11	...	72	29	40·3	3·1	63	...	30	30	100·0	17·8	534	...
3 . .	52	28	53·8	1·3	36	...	80	41	51·2	1·1	45	...	40	40	100·0	14·3	572	...
4 . .	66	7	10·6	1·4	10	66	22	13	59·1	1·4	18	106	20	20	100·0	19·4	388	1,863
Average .	...	...	37·5	...	...	66	...	...	56·6	...	...	106	...	...	100·0	...	...	1,863

Similar experiments conducted on *sarson* in 1929-30 (Table IV) show that the results in this case are also similar to those obtained in the case of *toria*. It will also be seen that even slightly better pod-setting and seed-production were obtained with artificial crossing than in the case of free-flowering branches, which is plausible on the assumption that in the case of free-flowering branches a small number of flowers might have been pollinated with their own pollen.

TABLE IV

Comparison of setting in sarson, *of untouched, artificially selfed and crossed flowers under bag and flowers left unbagged, in the year 1929-30*

Plant No.	Bagged only (otherwise) untouched						Bagged and artificially selfed (Hand-pollinated)						Free flowering						Bagged and crossed					
	Total number of flowers treated	Total number of pods formed	Percentage of setting	Average number of normal seeds per pod	Total number of normal seeds	Number of normal seeds calculated per 100 flowers	Total number of flowers treated	Total number of pods formed	Percentage of pod-setting	Average number of normal seeds per pod	Total number of normal seeds	Average number of normal seeds calculated per 100 flowers	Total number of flowers treated	Total number of pods formed	Percentage of pod-setting	Average number of normal seeds per pod	Total number of normal seeds	Average number of normal seeds calculated per 100 flowers	Total number of flowers treated	Total number of pods formed	Percentage of pod-setting	Average number of normal seeds per pod	Total number of normal seeds	Average number of normal seeds calculated per 100 flowers
1 . .	25	8	32·0	1·4	11	...	25	10	40·0	2·9	29	...	22	18	81·8	14·8	266	...	27	27	100·0	14·2	384	...
2 . .	Branches damaged												10	10	100·0	11·6	116	...	11	11	100·0	13·3	146	...
3 . .	80	17	21·2	1·5	25	...	8	3	37·5	1·3	4	...	20	19	95·0	15·8	300	...	25	25	100·0	20·8	521	...
4 . .	37	7	18·9	2·8	20	...	26	10	38·6	2·8	28	...	16	15	93·7	21·3	319	...	26	26	100·0	19·4	504	...
5 . .	84	33	39·3	2·4	80	60	30	19	63·3	3·7	44	118	10	10	100·0	24·4	244	1,596	17	17	100·0	24·3	411	1,855
Average .	...	...	29	...	...	60	...	...	47	...	...	118	...	...	92	...	...	1,596	...	...	100·0	...	...	1,855

In brown-seeded *sarson* also, as in *toria*, pods formed as a result of crossing are much bigger and contain incomparably greater number of seeds than the pods produced by natural or artificial selfing. Results of experiments bearing on these points, both for *toria* and *sarson*, are tabulated in Table V.

TABLE V

Reduction which takes place on selfing, in toria *and* sarson *in the length of pods and number of normal seeds*

Crop	Year	Treatment of flowering branches	Number of flowers treated	Average length in centimeters per pod				Average No. of normal seeds per pod
				Entire pod	Pedicel	Seed bearing portion	Beak	
Toria . .	1927-28	Bagged . . .	1,997	4·46	1·42	2·05	0·99	1·33
		Free-flowering .	472	6·84	1·53	3·95	1·36	15·48
	1929-30	Bagged . . .	248	4·77	1·67	2·17	0·93	1·50
		Hand-selfed . .	242	5·15	1·72	2·40	1·03	2·00
		Artificially crossed .	140	8·95	1·77	5·42	1·76	18·45
Sarson brown-seeded	1927-28	Bagged . . .	606	5·30	1·50	2·40	1·40	1·86
		Free-flowering .	145	6·60	1·60	3·60	1·40	6·18
	1929-30	Bagged . . .	226	4·72	1·75	2·25	0·72	2·02
		Hand-selfed . .	89	5·02	1·60	2·47	0·93	2·67
		Free-flowering .	68	7·70	1·95	4·35	1·40	19·07
		Artificially . .	95	8·10	1·75	4·90	1·45	19·67
Sarson yellow-seeded	1927-28	Bagged . . .	104	7·10	1·50	4·10	1·50	14·01
		Free-flowering .	91	7·10	1·60	4·30	1·20	17·11

These figures show that in by far the most of the cases natural or artificial selfing in *toria* and brown-seeded *sarson* reduces the length of the pods to $\frac{1}{2}$ to $\frac{2}{3}$ of that given by 'crossed' flowers and the number of seeds per pod to 1/12 to 1/6. As already stated, the loss of length which takes place in the pod is mainly confined to its seed-bearing portion, affects the beak very slightly, and has practically no effect on the pedicel.

From Table V it will also be seen that very little reduction of this sort takes place in the yellow-seeded form of *sarson*. As already shown in Table I above, this particular form of *sarson*, unlike brown-seeded forms, gives an exceptionally good setting under bag due to the floral mechanism affording facilities for self-pollination. As shown in the case of *toria* and brown-seeded forms of *sarson*, facilities for self-pollination alone are not sufficient. The plant must have the quality of self-compatibility, which quality the yellow-seeded form of *sarson* seems actually to possess.

(*D*) *Effect of self-pollination treatment at different stages of flower development on pod and seed setting*

As already stated the different pollination treatments in the experiments referred to above were in each case given to freshly opened flowers, *i.e.*, on the same morning on which the flowers opened. Experiments were carried out both in the case of *toria* and brown-seeded *sarson* in the years 1931-32 and 1932-33 to find out the effect of self-pollinating the stigmas artificially in the flower buds and in the open flowers of various ages. For pollination in the bud stage a number of flower-buds in an inflorescence were self-pollinated on a particular day, and later on the number of flowers was counted as they opened each day. The opened flowers were labelled daily in order to find out the time the bud was self-pollinated, before it opened into a flower. Thus it was possible to trace out the number of days a particular flower was self-pollinated in the bud-stage before opening. In the cases where flowers were self-pollinated certain days after opening, similar records were kept about the days on which flowers opened and these flowers were later self-pollinated at the required time. The results are tabulated in Table VI.

TABLE VI

Results of differential self-pollination treatment on pod and seed-setting in toria *and* sarson *for the years 1931-32 and 1932-33*

Treatment	*Toria*									*Sarson* (Brown-seeded)									
	Total number of flowers treated	Total number of pods formed	Percentage of pod-setting	Average length in cm. per pod: Entire pod	Pedicel	Seed bearing portion	Beak	Average number of normal seeds per pod	Total number of normal seeds.	Average number of normal seeds calculated per 100 flowers.	Total number of flowers treated	Total number of pods formed	Percentage of pod-setting	Average length in cm. per pod: Entire pod	Pedicel	Seed-bearing portion	Beak	Average number of normal seeds per pod	Total number of normal seeds	Average number of normal seeds calculated per 100 flowers
Selfed one day before opening	78	40	51·3	6·2	1·9	3·0	1·3	3·4	136	174	80	15	18·8	5·3	1·8	2·0	1·5	1·0	15	19
Selfed two days before opening	76	74	97·4	8·5	1·8	4·8	1·9	9·3	688	905	90	60	66·7	5·9	1·7	2·4	1·8	2·8	168	187
Selfed three days before opening	88	88	100·0	8·7	1·7	4·9	2·1	9·1	801	910	78	78	100·0	8·8	1·8	4.3	2·7	10·2	796	1,021
Selfed four days before opening	76	72	94·7	7·3	1·7	3·3	2·3	5·4	389	512				Damaged						
Selfed same day . . .	145	68	47·6	5·1	1·7	2·3	1·1	1·9	129	89	114	23	20·2	5·0	1·7	1·9	1·4	1·5	35	31
Free flowering . . .	80	78	97·5	7·8	1·7	4·7	1·4	17·4	1,357	1,696	93	90	96·8	8·5	2·0	4·4	2·1	16·4	1,476	1,587
Selfed one day after opening.	71	21	29·6	4·7	1·6	2·1	1·0	2·4	50	70	74	34	45·9	6·1	2·1	2·9	1·1	3·0	102	138
Selfed two days after opening	121	78	64·5	6·1	2·2	2·6	1·3	2·8	218	180	74	51	68·9	6·9	2·1	3·1	1·7	3·0	153	207
Selfed three days after opening	81	60	74·1	5·8	2·1	2·7	1·0	3·4	204	252	89	54	60·7	6·3	1·9	2·7	1·7	3·1	167	188
Selfed four days after opening	84	42	50·0	5·6	2·0	2·5	1·1	2·0	84	100	90	50	55·6	5·1	1·8	2·2	1·1	0·9	45	50
Selfed five days after opening.	78	27	34·6	5·2	2·2	2·2	0·8	1·4	38	49	53	8	15·1	5·8	2·1	2·4	1·3	1·6	13	25
Selfed same day . . .	127	46	36·2	5·2	1·9	2·3	1·0	2·0	92	72	94	42	44·7	5·7	2·0	2·4	1·3	1·0	42	45
Free-flowering . . .	139	135	97·1	8·0	2·1	4·3	1·6	18·0	2,430	1,743	116	111	95·7	7·7	1·9	4·4	1·4	15·9	1,765	1,522

The figures show that by self-pollinating a flower bud two and three days in the case of *toria* and three days in the case of brown-seeded *sarson* before it opens out into a flower, quite a good pod-setting and seed-production is obtained, which compares favourably with that on free flowering branches. In fact by self-pollinating a bud three days before opening cent per cent pod setting has been obtained as compared to 97·5 per cent and 96·8 per cent obtained in the case of free flowering branches in *toria* and *sarson* respectively, so that normally self-incompatible plants become highly self-fertile when flowers are pollinated in bud stage. Similar phenomenon has been reported in the case of some other species of Cruciferae by Kakizaki and Kasai [1933], who designate this phenomenon as ' pseudo-fertility '. It may be argued that the increase in self-fertility by bud-pollination is due to the comparatively smaller length of the styles in the flower-buds than that in the case of opened flowers and, therefore, pollen tubes, which are believed to attain an insufficient length when selfing is resorted to, are not capable of reaching the ovary and fertilizing the ovules. But when further it is considered that in the above experiments the flowers self-pollinated two or three days after the opening gave much better pod-setting and seed production than those selfed on the same day when they opened or one day after their opening, this assumption does not appear to hold good absolutely as the styles are decidedly longer in the two or three days old flowers than in the freshly opened or one day old flowers. Akhtar [1932] working on some Indian Brassicae has concluded that pollen tubes grow more quickly in compatible unions than in incompatible matings and that sterility in incompatible matings is due to the failures of the pollen tubes to reach the ovules before it has lost its receptive power. It has been shown by the investigation of Jost [1907], Martin [1913] and Silow [1931], that self-sterility in red clover (*Trifolium pratense* L.), is due to the slower growth of ' self ' pollen than of foreign pollen in the styler tissue and that this may be accounted for by an inhibiting action of that tissue. From the results quoted above, however, it is evident that in the case of *toria* and brown-seeded *sarson* this kind of inibiting action in the styler tissue, is not equally effective in flowers, of different ages. In fact it does not seem to act effectively at all when selfing is done in buds three days before they open into flowers. It, therefore, appears more likely that in the case of *toria* flowers this secretion is produced most actively from one day before opening to one day after opening, while in *sarson* flowers it is produced from about two days before opening to one day after opening. As will be shown later, the fall in the pod-setting and seed production after the flower is more than three days old is due to the fall in the receptivity of the stigma.

(*E*) *Duration of the period of receptivity of stigma and viability of pollen grains*

A detailed study of the period for which the stigma remains receptive and the pollen grains viable was carried out in the years 1930-31 and 1931-32. The

following three different sets of artificial cross-pollination experiments in *toria* and brown-seeded *sarson* were arranged :—

(*a*) Pollen from freshly opened flowers was applied to stigmas of different ages, *viz.*, one to six days after the opening of flowers.

(*b*) Stigmas of freshly opened flowers were treated with pollen grains of varying ages, *viz.*, one to nine days after the opening of flowers.

(*c*) Different combinations of pollen grains and stigmas of varying ages ranging from one to three days after the opening of flowers were tried.

The results obtained by giving differential pollination treatment in each set of these experiments were compared with the results obtained by applying fresh pollen to fresh stigmas and also with those obtained from the free flowering branches of the same plant left open to the visits of insects. From the data obtained (Table VII) the following conclusions are drawn.

(*i*) *Length of the period of receptivity of stigmas as shown by their being treated with fresh pollen.*—Although there was a decline in pod-setting with an advance in the age of the stigma, yet a fair amount of setting was obtained in the case of even four days old stigma. The percentage of pod-setting is, however, very low in the cases of five or six days old stigma. The pod-setting and seed production was normal in the cases where one to two days old stigmas were pollinated. In the case of stigmas, three days old, a decline in the seed production occurred and the number of seeds produced per pod in this case was about 3/5 and 2/3 respectively of those obtained from the pods formed as a result of the application of fresh pollen to fresh stigmas and from the pods formed on free flowering branches. Further, with four days old stigmas a great fall in the number of seeds produced per pod occurred and this fall was still greater in the case of the five and six days old stigmas, the number of seeds per pod in the latter case being only 2·3 in *toria* and 2·7 in brown-seeded *sarson* as against 16·1 and 19·7 respectively obtained from the free flowering branches of these crops. These results therefore, indicate that after the opening of the flower the stigma remains fairly receptive for three days after which time there occurs an appreciable fall in pod and seed production, so much so, that with five days old stigmas very little pod setting and seed formation are obtained. Sepals and petals of *toria* flowers are shed on the fourth or fifth day after the opening of the flowers. Therefore, the decrease in pod setting and seed production seems to be associated with the withering away of sepals and petals so that the condition of sepals and petals in *toria* flowers may serve as an indication of the degree of receptivity of the stigma.

(*ii*) *Length of the period of viability of pollen grains.*—Quite normal pod setting and seed production have been obtained by treating fresh stigmas with pollen grains of varying ages. From the results obtained it is evident that in the case of *toria* sufficient number of pollen grains, to bring about normal setting and seed production, remain viable for seven days after collection from the freshly opened flowers. In

the case of brown-seeded *sarson*, however, they appear to remain viable for even a slightly longer period.

(*iii*) *Stigmas and pollen grains of varying ages.*—Various combinations of one to three days old pollen grains and stigmas have shown quite normal pod setting in almost all cases.

Considering the above results as a whole it is concluded that stigmas in *toria* and *sarson* remain fairly receptive for at least three days after the opening of flowers and pollen grains remain viable for at least seven days. These results have proved very helpful in some of the breeding investigations being carried out on these crops.

TABLE VII

Showing the result of pollination experiments in toria *and* sarson *with stigmas and pollen grains of different ages during the years 1930-31 and 1931-32*

Treatment	TORIA										SARSON (Brown-seeded)									
	Total number of flowers treated	Total number of pods treated	Percentage of pod-setting	Average length in cm. per pod				Average number of normal seeds per pod	Total No. of normal seeds	Average No. of normal seeds calculated per 100 flowers	Total number of flowers treated	Total No. of pods formed	Percentage of pod-setting	Average length in cm. per pod				Average No. of normal seeds per pod	Total No. of normal seeds	Average No. of normal seeds calculated per 100 flowers
				Entire pod	Pedicel	Seed-bearing portion	Beak							Entire pod	Pedicel	Seed-bearing portion	Beak			
One day old stigma and fresh pollen	110	108	98·2	8·8	2·2	5·8	1·0	15·4	1,663	1,512	85	78	91·8	11·2	2·7	6·0	2·5	19·8	1,544	1,816
Two days old stigma and fresh pollen	102	98	96·1	8·5	1·8	5·0	1·7	17·1	1,676	1,643	96	91	94·8	10·0	2·4	5·3	2·3	17·0	1,547	1,611
Three days old stigma and fresh pollen	104	99	95·2	7·6	2·1	4·1	1·4	15·5	1,535	1,476	85	72	84·7	8·6	2·1	4·9	1·6	13·6	97	1,152
Four days old stigma and fresh pollen	100	81	81·0	7·1	2·3	3·0	1·8	4·4	356	356	87	57	65·5	7·2	2·0	3·7	1·5	9·9	564	648
Five days old stigma and fresh pollen	80	34	42·5	5·1	2·1	2·1	0·9	2·3	78	98	105	66	62·9	6·7	1·9	3·5	1·3	7·6	502	478
Six days old stigma and fresh pollen	72	30	41·7	5·1	2·0	2·0	1·1	2·3	69	96	25	4	16·0	6·4	2·2	2·1	2·1	2·7	11	44
Fresh stigma and fresh pollen .	106	104	98·1	9·9	2·4	5·3	2·2	17·9	1,862	1,757	146	133	91·1	9·1	2·2	4·9	2·0	15·5	2,062	1,412
Free flowering . . .	124	120	96·8	8·1	2·2	4·3	1·6	16·1	1,932	1,558	103	99	96·1	8·5	2·1	4·7	1·7	19·7	1,950	1,893

TABLE VII—*contd.*

Showing the result of pollination experiments in toria *and* sarson *with stigmas and pollen grains of different ages during the years 1930-31 and 1931-32*

Treatment	TORIA										SARSON (Brown-seeded)									
	Total number of flowers treated	Total number of pods treated	Percentage of pod-setting	Average length in cm. per pod				Average number of normal seeds per pod	Total No. of normal seeds	Average No. of normal seeds calculated per 100 flowers	Total number of flowers treated	Total No. of pods formed	Percentage of pod-setting	Average length in cm. per pod				Average No. of normal seeds per pod	Total No. of normal seeds	Average No. of normal seeds calculated per 100 flowers
				Entire pod	Pedicel	Seed-bearing portion	Beak							Entire pod	Pedicel	Seed-bearing portion	Beak			
One day old pollen and fresh stigma	112	111	99·1	8·4	2·1	4·9	1·4	12·6	1,399	1,249	109	109	100·0	9·7	1·9	5·9	1·9	19·5	2,126	1,950
Two days old pollen and fresh stigma.	125	121	96·8	8·6	2·0	5·0	1·6	13·8	1,670	1,336	117	116	99·1	9·6	1·9	5·7	2·0	17·5	2,030	1,735
Three days old pollen and fresh stigma	109	108	99·1	9·4	2·2	5·5	1·7	18·9	2,041	1,872	115	111	96·5	9·7	1·7	6·0	2·0	17·4	1,931	1,679
Four days old pollen and fresh stigma	120	116	96·7	8·9	2·2	4·8	1·9	19·8	2,297	1,906	97	94	96·8	8·5	1·8	4·7	2·0	15·1	1,419	1,463
Five days old pollen and fresh stigma	108	99	91·7	8·7	2·1	4·6	2·0	16·6	1,643	1,521	108	101	93·5	8·7	1·8	4·9	2·0	14·0	1,414	1,309
Six days old pollen and fresh stigma	82	82	100·0	8·2	1·7	4·7	1·8	10·0	820	1,000	47	44	93·6	9·6	1·7	5·0	1·9	12·7	559	1,189
Seven days old pollen and fresh stigma	86	82	95·4	8·3	1·6	4·8	1·9	12·2	1,000	1,163	37	29	78·4	7·0	2·0	3·8	1·2	10·0	290	784
Eight days old pollen and fresh stigma	72	58	80·6	5·6	1·3	3·3	1·0	7·4	429	596	41	40	97·6	8·9	2·5	4·5	1·9	9·8	392	956
Nine days old pollen and fresh stigma	65	50	76·9	4·6	1·3	2·4	0·9	2·2	110	169	47	45	95·7	6·6	1·6	3·6	1·4	9·4	423	900
Fresh stigma and fresh pollen .	147	143	97·3	8·8	1·9	5·3	1·6	16·2	2,317	1,576	102	99	97·1	9·2	2·0	4·9	2·3	16·5	1,634	1,602
Free flowering . . .	178	174	97·8	7·3	1·8	4·1	1·4	16·1	2,801	1,574	141	141	100·0	8·0	2·1	4·7	1·2	17·3	2,439	1,730

One day old stigma and one day old pollen	50	49	98·0	8·6	2·2	4·6	1·8	13·0	637	1,274	32	32	100·0	7·9	2·3	3·9	1·7	12·0	384	1,200
One day old stigma and two days old pollen	44	42	95·4	9·2	2·3	5·5	1·4	14·1	592	1,345	26	26	100·0	8·4	2·2	4·2	2·0	16·0	416	1,600
One day old stigma and three days old pollen	37	34	91·9	9·3	2·1	5·4	1·8	16·1	547	1,479	26	25	96·1	8·1	2·2	4·1	1·8	14·0	350	1,346
Two days old stigma and one day old pollen	47	47	100·0	8·0	2·0	4·9	1·1	16·9	794	1,689	32	31	96·9	7·7	2·0	3·8	1·9	17·2	533	1,666
Two days old stigma and two days old pollen	46	46	100·0	8·5	2·1	5·0	1·4	14·4	662	1,439	35	35	100·0	7·1	1·9	3·4	1·8	14·0	490	1,400
Two days old stigma and three days old pollen	46	46	100·0	8·3	1·9	5·0	1·4	16·9	777	1,689	32	32	100·0	7·2	1·9	3·8	1·5	18·2	582	1,819
Three days old stigma and one day old pollen	24	24	100·0	9·9	2·3	5·6	2·0	15·	70	1,541	35	35	100·0	6·6	1·8	3·4	1·4	14·3	501	1,431
Three days old st ,d two days old pollen	25	25	100·0	9·3	2·1	5·4	1·8	16·7	418	1,672	35	35	100·0	7·3	1·9	3·6	1·8	17·0	595	1,700
Three days old stigma and three days old pollen	24	22	91·7	9·7	2·4	5·3	2·0	15·3	337	1,404	30	30	100·0	6·0	1·7	2·9	1·4	10·5	315	1,050
Fresh stigma and fresh pollen .	111	109	98·2	9·2	2·1	5·2	1·9	18·0	1,962	1,768	82	81	98·8	7·4	1·9	3·6	1·9	13·6	1,102	1,344
Free flowering . .	85	85	100·0	8·1	2·5	4·4	1·2	17·4	1,479	1,740	60	60	100·0	7·4	2·6	3·6	1·2	17·4	1,044	1,740

V. Breeding of improved varieties of *toria* and *sarson*.

(*A*) *Evolution of unit species*

From the results of self and cross fertilization experiments mentioned above it is natural to expect that inbreeding (self-fertilization) in *toria* and brown-seeded *sarson* would result in loss of vigour. This has actually been observed to be the case. The plants raised from selfed seed were usually found to be short statured and much less vigorous than those raised from seeds obtained by crossing. Actual determinations were made in 1931-32 with regard to the height of plants, number of branches, and percentage of flowers that set into pods in the plants raised from seeds obtained from selfing and crossing. The average results are given below :—

Name of crop	Seed obtained by	No. of plants studied	Average height of plants in cm.	Average number of primary branches per plant	Average percentage of pod-setting
Toria . .	Selfing . . .	50	93·4	9·4	41·4
	Crossing . .	100	109·4	11·3	46·7
Brown-seeded *sarson*	Selfing . . .	50	90·5	7·4	39·8
	Crossing . .	100	112·5	10·5	50·2

Thus it is evident that the plants raised from seeds obtained by crossing attained greater height, produced more branches, and formed greater number of pods than those raised from selfed seed. No determinations were made as regards the size of pods, weight of seeds and number of seeds per pod. But from a general examination of the material it was quite apparent that in these respects too the plants raised from seeds obtained by crossing scored over those raised from selfed seed. Many of the seeds obtained by natural selfing did not germinate at all.

In light of the above it will be seen that, in *toria* and brown-seeded *sarson*, pure lines, though they can be produced by continued (enforced) inbreeding, have, as such no utility for the farmer. In the case of yellow-seeded *sarson*, however, which is self-fertile, a large number of unit species or types have been isolated from the mixtures commonly grown in some parts of the province, some of which are very promising.

(*B*) *Mass selection and the factors concerned*

From the facts mentioned above it is clear that crossing in *toria* and brown-seeded *sarson* is a sure means of obtaining high yields, which in the breeding of improved varieties should not be excluded. Crossing should, however, be limited

to certain desirable forms, so that some sort of group breeding or mass selection should be resorted to in order to effect improvement in these crops. Mass selection consists of selecting such plants as possess the desirable attributes. By following this method considerable improvement of these two crops has already been effected in the Punjab. This is borne out by the following facts regarding the work done on *toria* crop. To start with, it may be noted that in the case of *toria* crop, the desirable or choice plants should for various reasons possess the following attributes.

1. They should be fairly early so that growth of plants and development of fruit may be completed before the season gets too cold and frosty. Uniformity in maturing is essential to avoid difficulties in harvesting.

2. Habit should be profusely branching, with branches ascending so that the form of the plant should be more or less like that of an inverted cone. Plants having wide, open tops or those having few branches should be discarded. The former occupy too much space for the yield they give.

3. The branches should possess the capacity of profuse podding.

4. Pods should be long, containing bold seeds, as bolder seeds contain a higher percentage of oil. Relative weight of seeds would be an indication of their boldness and it is interesting to note that the colour of freshly harvested seeds in *toria* and brown-seeded *sarson* has been found to be correlated with their weight. This correlation in addition to having a commercial utility can serve a very useful purpose in selection work. A sample of seeds of *toria* and brown-seeded *sarson* obtained from one and the same plant usually contains two differently coloured types of seeds, *viz.*, light brown or reddish and deep brown or blackish. A comparison between the weight of these blackish and reddish seeds (Table VIII) shows that red seeds weigh less than the black seeds. On the average one hundred blackish seeds weigh about 21 per cent and 35 per cent higher in *toria* and *sarson* respectively than the reddish seeds. This difference is probably due to the difference in nutrition as it has been found that both in *toria* and *sarson* black or blackish seeds predominate in the basal portions of the branches. This predominance is in case of *toria* reversed towards the middle of a branch and further on, the predominance of red or reddish seeds becomes greater and greater until at the top there are about 3 of them to 1 of black or blackish seeds. But, in *sarson* it goes a long way up and it is only at the tip that it suffers a diminution. During the year 1932-33 there was frost during the seed development period of *toria* and development of seeds was consequently adversely affected. It was found that the produce contained an exceptionally large number of reddish seeds This fact also lends support to the assumption that development of colouration is associated with nutrition. A point of still greater interest from the breeder's point of view is the fact that the *toria* plants raised from blackish seeds have been found to grow taller, bear more pods, yield comparatively heavier seeds and give a higher yield per plant than those raised from the reddish seeds.

TABLE VIII

Comparing the weight of black and red seeds in toria *and* sarson, *1927-28*

Plant No.	*Toria*			*Sarson*		
	Weight in grams per 100 seeds			Weight in grams per 100 seeds		
	Black	Red	Difference in favour of black seeds	Black	Red	Difference in favour of black seeds
1 . . .	0·340	0·262	0·078	0·567	0·378	0.180
2 . . .	0·347	0·330	0·017	0·471	0·352	0.119
3 . . .	0·445	0·365	0·080	0·366	0·295	0.071
4 . . .	0·331	0·215	0·116	0·357	0·295	0·062
5 . . .	0·355	0·310	0·045	0·416	0·301	0·115
6 . . .	0·370	0·265	0·105	0·427	0·332	0·095
7 . . .	0·351	0·317	0·034	0·397	0·269	0·128
8 . . .	0·330	0·295	0·035	0·414	0·295	0·119
9 . . .	0·367	0·315	0·052	0·383	0·299	0·084
Average. .	0·359	0·297	0·062	0·422	0·313	0·109
In terms of 100 . .	121	100	21	135	100	35

Determinations made in 1931-32 with regard to these characteristics are as follows :—

Progeny of	No. of plants studied	Average height per plant in cm.	Average No. of primary branches	Average No. of pods per plant	Average weight of 100 seeds in grms.	Average yield per plant in grms.
Blackish seeds	100	168	11	846	0·235	33·56
Reddish seeds	100	163	11	735	0·220	26·44

Thus it is apparent that the plants raised from the blackish seeds give about 27 per cent more yield per plant than those raised from reddish seeds. Selection of plants on the basis of high percentage of blackish seeds would therefore be a decided advantage.

It may also be mentioned that the yield per plant in *toria* has been found to be more or less positively correlated with the number of primary branches, length of pods, and weight of 1000 seeds. The correlation worked out from the data obtained in the year 1932-33 are as follows :—

Characters related	No. of pairs of values used	$R \pm$P. E.	Correlations
No. of primary branches and yield per plant	190	$+0{\cdot}63+0{\cdot}029$	Very high, positive, significant
Length of pods and yield per plant	181	$0{\cdot}39\pm0{\cdot}042$	High, positive, significant
Weight of 1000 seeds and yield per plant	147	$\pm0{\cdot}18\pm0{\cdot}054$	Low, positive, not significant

Considering the various results quoted above, it is evident that in order to obtain high yielding selections profusely branched plants with longer pods and comparatively bold seeds, majority of the seeds being blackish in colour, should be selected. On the basis of these considerations the selection work on *toria* and *sarson* crops has been carried out in the Punjab during the past several years and the selected strains have invariably been giving one to two maunds more yield per acre than the unselected strain.

(*C*) *Hybridization*

A number of intercrosses were attempted between *toria* and *sarson* and between them and some other Brassicae. The results of some of the earlier studies [Ali Mohammad, Singh and Alam, 1931] showed that the different species of the genus Brassicae referred to above crossed readily with one another and the pods and seeds formed as a result of these crosses were quite normal as compared with pods and seeds formed on free flowering branches of the seed parent in each case. The investigations on these crosses have to be continued further for a number of years before any definite conclusions can be drawn. Reference is, however, made to a few important points which have come to light as a result of some of these studies and have added greatly to the results of the pollination studies referred to above, in so far as the improvement of the two crops under

consideration, *viz.*, *toria* and *sarson*, is concerned. From the results of the various pollination experiments it has already been pointed out that the common brown-seeded forms of *toria* and *sarson* are high self-sterile giving very poor setting under bag and are extensively cross pollinated in nature, depending almost entirely on insects for their pollination. Yellow-seeded form of *sarson*, on the other hand, is self-fertile, giving very good setting under bag. The yellow-seeded form of *sarson* has been intercrossed reciprocally with both *toria* and brown-seeded form of *sarson* in order to evolve strains which in addition to possessing all the desirable characteristics of *toria* and brown-seeded *sarson* should have the invaluable merit of being self-fertile like the yellow-seeded *sarson*. These studies are being pursued further but from the results so far achieved it is evident that self-fertility behaves as an inherited character independent of colour of seed and it has been found possible to obtain self-compatible plants having brown seeds like the common forms of *toria* and *sarson*. Therefore, the former idea that there is a close association between self-fertility and yellowness of seeds should be abandoned. The investigations into the various aspects of the problem connected with the inheritance of characters will form the subject for discussion in a separate paper but a special point of practical interest which has come to light as a result of these hybridization studies is the possibility of introducing self-fertility into the brown-seeded forms of *toria* and *sarson* referred to above. This would give a decided advantage as the self-fertile strains would not depend on insects for their pollination and therefore, the periodic failure of these crops due to insufficiency of insect visitors would entirely vanish. The evolution of highly improved types of plants involves the study of several other plant characteristics about the inheritance of which nothing definite can yet be stated. The line of work being followed is very hopeful, but the success will depend on how far the plants raised in the future generations show combinations of various valuable and economic characteristics. There is no reason to doubt that as a result of these studies, there is a great possibility of the production of entirely new forms of *toria* and *sarson* superior to those now in existence, but the evolution of such highly improved strains is a matter of gradual selection by a series of steps. It is particularly note-worthy that as a result of the studies referred to above in this paper, abundant material has now become available which is sure to yield results of far greater value than those already obtained.

VI. Summary

1. *Toria* and *sarson*, for which the botanical names *Brassica napus L.* var. *dichotoma* Prain, and *Brassica campestris* L. var. *sarson* Prain, have been used in this paper on the authority of Prain, are by far the most important oilseed plants of the Punjab.

2. In both of them, the floral mechanism is such that it provides few chances for natural selfing. Under bags they are shy seed-setters. On an average of six years, only 12·3 and 20·3 per cent, respectively, of *toria* and *sarson* flowers formed

pods under such conditions and many of these pods were pods in name only with their seed bearing portions greatly reduced.

3. Yields of *toria* are adversely affected if there occur in November long spells of cloudy, humid, rainy weather. This is due to the fact that insects do not come out on such days to pollinate the flowers. *Andrena ilerda*, *Apis florea*, and *Halictus sp.* are the chief insect pollinators of *toria* and *sarson*.

4. Artificial selfing in *toria* and brown-seeded *sarson* by hand-pollination, at the time when flowers open, though it hardly increased the number of normal seeds per pod, makes some increase in the number of pods set. This increased production remains far short, however, of that on the free-flowering branches open to the visits of insects.

5. From crossing under bag and getting even a better setting than on free flowering branches, combined with the fact that artificial selfing does not improve matters much, it is concluded that the high amount of self-sterility prevailing in these two plants is not due to external causes alone, but due to internal ones (self incompatibility) also.

6. By self-pollinating a flower-bud two and three days, in the case of *toria* and three days in the case of brown-seeded *sarson*, before it opens out into a flower, quite a good pod-setting and seed production is obtained which compares favourably with that on free flowering branches.

7. Flowers self-pollinated two or three days after opening gave much better pod-setting and seed production than those selfed on the same day when flowers opened or a day after their opening.

8. The probable cause of self-sterility, as so far known, is the slow growth of 'self' pollen than of foreign pollen in the stylar tissue which is accounted for by an inhibiting action of that tissue. From the observations made it is argued that in *toria* and *sarson* this kind of inhibiting action is not equally effective in flowers of different ages and it appears more likely that in these plants this inhibiting action may be due mainly to the effect of a certain secretion produced actively in the stylar tissue between one to two days before and after the opening of the flowers.

9. Pollen grains in *toria* and *sarson* remain viable for at least 7 days after collection from the freshly opened flowers and the stigmas remain receptive for 3 days after the opening of flowers.

10. In both *toria* and *sarson* reddish coloured seeds weigh less than blackish coloured seeds. In the case of *toria*, number of primary branches, length of pods and weight of seeds have been found to be more or less positively correlated with yield per plant.

11. Owing to loss of vigour in *toria* and brown-seeded *sarson* by inbreeding, pure lines have no direct economic utility. To obtain improved varieties some sort of group breeding must be resorted to and considerable improvement has already been achieved by mass selection.

12. As a result of the hybridization studies in *toria* and *sarson* self-fertility is found to behave as an inherited character independent of colour of seed and self-compatible brown-seeded plants have been evolved. Abundant material has become available which shows the possibility of evolving entirely new self-compatible forms of *toria* and *sarson* superior to those now in existence.

REFERENCES

Akhtar, A. R. (1932). *Ind. J. Agric. Sci.* **2**, 280.

Ali Mohammad; Singh, R. D.; and Alam, Z. (1931). *Ind. J. Agric. Sci.* **1**, 109-136.

Balls, W. L., Templeton, J., Brown, C. H. and Kilani, M. (1929). *Bull. Ministry Agric. Egypt* No. **89**, 1-27.

Burkill, I. H. (1906, 1). *J. and Proc. Asiatic Soc. Bengal* **2**, 511-514.

——— (1906, 2). *J. and Proc. Asiatic Soc. Bengal* **2**, 515-520.

——— (1906, 3). *J. and Proc. Asiatic Soc. Bengal* **2**, 521-525.

——— (1907). *J. and Proc. Asiatic Soc. Bengal* **3**, 517-526,

——— (1908). *J. and Proc. Asiatic Soc. Bengal* **4**, 179-231.

——— (1911). *J. and Proc. Asiatic Soc. Bengal* **6**, 101-107.

Chittenden, F. J. (1914). *Ann. App. Biol.* **1**,

Farrar, C. L. (1931). *J. Econ. Ent.* **14**,

Fox Wilson, G. (1929). *Ann. App. Biol.* **16**.

Hendrickson, A. H. (1916). *Calif. Agric. Expt. Stn. Bull. No.* **274**, 127-132.

Hutson, R. (1926). *New Jersey Agric. Expt. Stn. Bull.* **434**.

Hooper, C. H. (1923). ' The value of hive and wild bees in the production of fruit '.

Howard, A. Howard, G. L. C. and Abdur Rahman Khan (1910). *Mem. Dept. Agric. Ind., Bot. Ser.* **3**, No. 6.

Jost, L. (1907). *Uber die Selbst-sterilitat einiger Blutn. Bot. Ztg.* **65**.

Kakizaki, Y. and Kasai, T. (1933). *J. Hered.* **24**, 359-360.

Lewis, C. I. and Vincent, C. C. (1909). *Ore. Agric. Exp. Stn. Bull.* **104**.

Martin, J. N. (1913). *Bot. Gaz.* **56**.

Morris, O. M. (1921). *Washington Agric. Exp. Stn. Bull.* **163**, 1-32.

Nelson, (1927). *J. Gen.* **19**.

Overholser, E. L. (1927). *Calif. Agric. Exp. Stn. Bull.* **426**, 1-17.

Pammel, L. H. (1923). *Iowa Rept. State Apiarist* 1922, pp. 51-60, Iowa, 1923 (R. A. E. A. 1924 p. 18).

Phillipe, E. F. (1930). *J. Econ. Ent.* **23**, 218-223.

Prain (1898). *Agric. Ledger* **1**.

Silow (1931). *Welsh P. B. Station, Series H, No.* **12**, 1921-1930.

Treherne, R. C. (1923). *15th Ann. Rept. Quebec. Soc. Pro. Plants*, 1922-23, pp. 47-59, Quebec 1923 (R. A. E. A. XI, p. 477).

Walton, C. L. (1927). *Ann. App. Biol.* **14**, 465-469.

Williams, R. D. (1925). ' Studies concerning the pollination, fertilization and breeding of red clover. '

Branched and normal ear-heads from one F_2 plant in a cross between Chevalier and Pusa Type 21 barleys.

STUDIES IN INDIAN BARLEYS

3. BRANCHED EARS IN BARLEY AND THEIR MODE OF INHERITANCE

BY

R. D. BOSE, B.Sc.,

Officiating Assistant Economic Botanist, Pusa

(Received for publication on 4th December 1934)

(With Plate X)

A small number of plants with branched earheads were observed in 1931-32 in the F_2 population of a cross between Chevalier (2-rowed) and Pusa Type 21 (6-rowed) barleys. The branching was invariably restricted to the lower half of the ear and only a few ears and not all exhibited this peculiarity in each plant. Plate X depicts a branched earhead as well as a normal unbranched ear from one and the same plant.

Branched ears of barley occur but very rarely in nature and indeed only a very few references exist about this phonomenon. In 1910 Tschermak recorded a case of inheritance of branched ears in barley and found that segregation for this character was on a monohybrid basis, the branched ear type being the recessive phenotype. Schneider [1913] described a new form of barley, which appeared in Posen in 1902, the chief feature of which was branching of the spikes—a characteristic which proved to be transmitted with constancy. Although this type of barley had a somewhat higher yielding capacity than ordinary varieties, the quality was said to be decidedly inferior. Schneider has also given a few interesting references some of which are quoted below.

" In 1671 a note was published mentioning the fact that a branched ear of barley which consisted of 15 larger and 9 smaller sized ears was found in 1637 in the country of Glatz in Silesia on a field which for a long time had been uncultivated, it was brought to the Emperor and engraved in stone ". Koernicke [1882] and Wittmack [1871] have also studied the peculiar appearance of branched ears. The latter holds that branching is not only caused by specially rich conditions of soil but partly also by abnormal weather conditions—great moisture in the spring or cold in the preceding winter. Koernicke, on the other hand, thinks that the influence of moisture and cold is not great, otherwise rye in the north would shew a more frequent occurrence of branched ears. He believes it possible however that an unfavourable winter, in which the plants are partly frozen, may cause a branching of the ears.

Rimpau [1899] found an individual plant with branched ears among 2-rowed barleys and made the type constant by selection (*Lander. Jahrb.* 1891, D. L. Pr. 1899. Nr. 79). A breeding experiment with branched barley with the intention of creating a marketable product was undertaken in 1900 at the Seed Breeding Institute, Aderstedt and is mentioned in an article by Hoffmann of Lichinia (in D L. Pr. 1903, Nr. 3, page 17). The original material was a branched individual plant belonging to a two-rowed drooping barley. It was assumed that it arose as a spontaneous variation. Herr Antsrat Wessling in Westeregeln bred a Chevalier barley which had a branched form (Fig. in Schonfeld, " Brangersten in Bilde " Verlag Paul Parey, Berlin). Schneider also reported the appearance of branched ears frequently in Goldthorpe barley and once in Groninger winter barley but believed that the character was not constant.

On the cause of the occurrence of branched ears the views of different people vary considerably but the phenomenon is mostly attributed to external influences. As mentioned above Koernicke and Wittmack assigned the change to soil and weather conditions, Kuhn of Halle (D. L. Pr. 1899, Nr. 79) believed in the influence of bacteria, while Rimpau assumed spontaneous variations. Hoffmann of Lichinia (D. L. Pr. 1903, Nr. 3) observed the branching during transformation of summer into winter forms. Tschermak [1910] holds that the branching of the ears occurs after previous hybridization and that wheat-rye hybrids show occasional luxuriant forms. Blaringhem [Siehe Fruwirth Zucht. Lander. Kultur pfl ; 4, 293] has succeeded in inducing branching of the axis by ' wounding '.

In wheat, branched ears have been recorded by many workers. Meunissier [1918] and Tschermak [1923] believed that the normal condition was dominant to the branched ear of *turgidum*, and that in F_2 the monohybrid type of segregation occurred. Nilsson-Leissner [1925] found some plants with branched ears among *spelta* individuals from the cross *spelta* × *vulgare*, the branched condition being recessive but dependent on several multiple genes. Biffen [1916] found branched ears among the offspring of the cross with normal types in *polonicum* × *vulgare*. Similarly Kezer and Boyack [1918] recorded branched ears in a cross between *vulgare* × *dicoccum* wheats.

Branched ears have also been observed in maize by Collins [1917] and by Kempton [1923] who reported that the character seemed to be recessive to the normal type of ear.

It is the purpose of this paper to describe the mode of inheritance of branched ears that has been observed at Pusa in a cross between Chevalier and Pusa Type 21 barleys.

Material and method

Chevalier barley was imported from England in 1927 and Type 21 was evolved by selection at Pusa in 1925 [Bose, 1931]. Since then both these types have been grown annually during the *Rabi* seasons, *viz.*, during the period October to March,

but not a single earhead with branched ears has upto now been observed in them. The cross between these two types was made in 1929-30 in order to study the inheritance of some characters in an interspecific cross between a 2-rowed (Chevalier) and a 6-rowed (Pusa Type 21) barley. Only two F_1 plants could be raised in the following year but neither of them showed any trace of this abnormality. When the F_2 generation of this cross was grown in 1931-32 it was observed for the first time that 21 plants in a total population of 374 showed some earheads with a branched nature. The extent of branching in individual ears varied considerably, three to five branches per ear being observed very frequently.

All the plants with branched ears invariably had narrow and lax earheads with very poorly developed grains. A good deal of sterility also occurred in most cases and the hybrids exhibiting this phenomenon appeared to be neither good for quality nor for producing good yields. The only importance of these branched ear types, therefore, lies in their academic value, and they are not expected to yield results of any economic importance.

F_2 Generation

The F_2 progeny, along with the parental types, was grown in a field of average fertility. The distance between individual plants was one foot within and about three feet between the rows. The genetic study of the inheritance of characters such as fertility of the lateral spikelet, colour of the leaf-sheath and in the auricle, maturity, etc., will form the subject of another communication. The present paper is limited simply to the inheritance of branched ears. Segregation in F_2 was as follows :—

	Cross	No. of plants with		Total
		Normal ears	Branched ears	
	G-1	185	12	197
	G-2	175	9	184
Observed	..	360	21	381
Calculated on 15 : 1 . .	..	357·2	23·8	..
Deviation = 2·8 $\frac{\text{Dev.}}{\text{S. E.}} = \frac{2·8}{4·7} = 0·6$.				

Therefore the fit between observed and expected frequencies was very close and indicated that duplicate factors were responsible for the inheritance of branched ears in this barley cross.

F_3 Generation

Thirty-four families of this cross were studied in the F_3 generation for this character. Three F_2 plants with branched earheads and thirty-one with normal ears were selected for this purpose. The progeny of the plants with branched ears bred true for this character and thus proved the recessive nature of this phenotype. Of the remaining 31 families, 17 gave families of from 61 to 84 plants all with normal unbranched ears, while 7 families gave approximately 15 normal : 1 branched and 7 gave approximately 3 normal : 1 branched. On a duplicate factor hypothesis the three types should have occurred in the proportions 14·46 : 8·27 : 8·27. Expectation was therefore closely realised. The behaviour of the F_3 families is shown below :—

Table I

F_3 breeding behaviour for the inheritance of branched earheads

No. of families	Nature of F_2 parent	F_3 behaviour	No. of families	
			Observed	Expected
31	Normal unbranched ears	Pure . . .	17	14·46
		Segregating—		
		3 : 1 . . .	7	8·27
		15 : 1 . . .	7	8·27
3	Branched ears .	Pure . . .	3	3

It will be noted that the discrepancy between the observed and expected numbers of families is not great. Table II shows the frequencies of normal and branched earheads in segregating F_3 families.

TABLE II

F_3 frequencies for normal and branched earheads

Family	No. of plants with		Total number of plants	χ^2	P
	Normal ears	Branched ears			
7 families segregating on 3 :1—					
G. 1-58	64	18	82	0·41	0·5
G. 1-129	38	15	53	0·31	0·6
G. 2-19	48	13	61	0·44	0·5
G. 2-51	57	17	74	0·16	0·7
G. 2-53	53	17	70	0·02	0·9
G. 2-61	51	14	65	0·42	0·5
G. 2-160	54	20	74	0·16	0·7
Total	365	114	479	0·37	0·5
7 families segregating on 15 : 1—					
G. 1-110	51	2	53	0·55	0·5
G. 1-120	73	4	77	0·15	0·9
G. 1-165	56	3	59	0·14	0·9
G. 2-30	58	5	63	0·31	0·6
G. 2-75	56	4	60	0·02	0·9
G. 2-146	63	4	67	0·01	0·9
G. 2-165	63	3	66	0·33	0·6
Total	420	25	445	0·30	0·6

From the foregoing it may be concluded that the F_3 studies confirm the F_2 hypothesis that duplicate factors are responsible for the inheritance of branched earheads in this cross of Chevalier × Pusa Type 21 barley.

F_4 Generation

In 1933-34 thirteen families of this cross were grown for the study of the F_4 generation. Six plants with normal ears from F_2 families breeding true for normal ears gave families of from 83 to 147 plants, all with normal ears. Two plants with branched ears from F_2 families breeding true for branched ears gave families of 146 and 150 plants, all with branched ears. Five plants with normal ears from segregating F_2 families, segregated in F_3, and also in F_4. Details are given in Table III.

Table III

F_4 frequencies for normal and branched earheads

Family	F_3 segregation	No. of plants with		Total number of plants	χ^2	P
		Normal ears	Branched ears			
G. 1-58-33 . . .	3 : 1	140	40	180	0·74	0·4
G. 1-58-91 . . .	3 : 1	104	37	141	0·12	0·7
G. 2-165-60 . . .	15 : 1	102	5	107	0·45	0·5
G. 2-165-49 . . .	15 : 1	91	8	99	0·57	0·5
G. 2-146-86 . . .	15 : 1	125	5	130	1·28	0·3

This study proves once more that duplicate factors only were responsible for the inheritance of branched earheads in the cross under consideration.

Relation of fertility with the branched type of ear

Chevalier barley belongs to the two-rowed species *Hordeum distichon* L. while Pusa Type 21 is a six-rowed type belonging to the species *H. vulgare* L. The two

forms therefore differ in the nature of the fertility of the lateral spikelets. The lateral spikelets in the two-rowed barleys remain abortive and thus there are only two rows of grains developing from the central spikelets. The lateral spikelets in the 6-rowed barleys, on the other hand, are fully fertile giving rise therefore to six rows of grains in the ear. When these two barleys are crossed, the F_1 plants show an intermediate type of fertility and the F_2 segregation is on a monohybrid basis. That the character of branched earheads in barley in this cross segregated independently of the factors responsible for the nature of fertility of the lateral spikelets was brought out by the occurrence of this phenomenon in all phenotypes for fertility in the F_2 generation. Thus of the 21 plants which exhibited this character of branched ears in F_2, six plants had ears of the 2-rowed type, four plants had ears of the 6-rowed type and the remaining eleven plants had ears of the intermediate type of fertility. This relation is shown in Table IV.

TABLE IV

Relation of fertility with the branched type of earhead in F_2

Cross	2-ROWED		INTERMEDIATE		6-ROWED		Total
	Normal	Branched	Normal	Branched	Normal	Branched	
G. 1 . . .	51	4	88	6	46	2	197
G. 2 . . .	39	2	91	5	45	2	184
Total observed	90	6	179	11	91	4	381
Expected	89.30	6.95	178.60	11.90	89.30	5.95	..

$\chi^2 = 0.8306$ P—Between 0.95 and 0.98

The fit between observed and expected ratios on the basis of independent segregation is quite close. The fertility character segregates on a 1 : 2 :1 ratio while the earhead character shows a segregation on a 15 : 1 basis. This is further confirmed by the behaviour of the segregating families in F_3 as shown in Table V.

TABLE V

Relation of fertility with the branched type of earhead in F_3

Family	F_3 segregation for earhead character	2-ROWED		INTERMEDIATE		6-ROWED		Total
		Normal	Branched	Normal	Branched	Normal	Branched	
G. 1-110	15:1	13	0	26	2	12	0	53
G. 1-120	15:1	19	1	38	3	16	0	77
G. 1-165	15:1	12	1	31	1	13	1	59
G. 2-30	15:1	17	1	28	3	13	1	63
G. 2-75	15:1	16	0	28	2	12	2	60
G. 2-146	15:1	14	1	34	2	15	1	67
G. 2-165	15:1	16	0	29	3	18	0	66
Total	observed	107	4	214	16	99	5	445
	Expected	104.25	6.95	208.50	13.90	104.25	6.95	..
	$\chi^2=2.3321$		$P=0.80$	nearly				
G. 1-58	3:1	14	5	34	9	16	4	82
G. 1-129	3:1	11	4	17	7	10	4	53
G. 2-19	3:1	11	3	24	7	13	3	61
G. 2-51	3:1	13	4	30	10	14	3	74
G. 2-53	3:1	14	5	24	9	15	3	70
G. 2-61	3:1	15	2	24	8	12	4	65
G. 2-160	3:1	12	4	27	11	15	5	74
Total	observed	90	27	180	61	95	26	479
	Expected	89.82	29.94	179.64	59.88	89.82	29.94	..

$\chi^2=1\cdot1279$ P—between 0.95 and 0.98

Discussion of results

From the results of the foregoing studies it may be concluded that the production of branched earheads in this cross of barley depends on the interaction of duplicate factors and that the branched ear phenotype acts as the double recessive.

Type 21 barley has never been observed to throw out any branched earheads and neither has the strain of Chevalier barley grown at Pusa for a number of years, but Herr Antsrat Wessling (page 156) bred a Chevalier barley having a branched form.

In the present case let N_1N_1 be a factor which produces normal development of the barley ear and let N_2N_2 be another factor which operates in the same way as N_1N_1. The complete absence of both N_1 and N_2 will therefore produce branched earheads. The genetic interpretation of this cross may be shown in the Punnet-square given below :—

P_1 $N_1N_1n_2n_2$ (Chevalier) Normal × $n_1n_1N_2N_2$ (Pusa T. 21) rmal

F_1 $N_1n_1N_2n_2$ (F_1 hybrids) Normal

F_1 Gametes → N_1N_2 N_1n_2 n_1N_2 n_1n_2

F_2

	N_1N_2	N_1n_2	n_1N_2	n_1n_2
N_1N_2	$N_1N_1N_2N_2$ 1 : 0	$N_1N_1N_2n_2$ 1 : 0	$N_1n_1N_2N_2$ 1 : 0	$N_1n_1N_2n_2$ 15 : 1
N_1n_2	$N_1N_1N_2n_2$ 1 : 0	$N_1N_1n_2n_2$ 1 : 0	$N_1n_1N_2n_2$ 15 : 1	$N_1n_1n_2n_2$ 3 : 1
n_1N_2	$N_2n_1N_2n_2$ 1 : 0	$N_1n_1N_2n_2$ 15 : 1	$n_1n_1N_2N_2$ 1 : 0	$n_1n_1N_2n_2$ 3 : 1
n_1n_2	$N_1n_1N_2n_2$ 15 : 1	$N_1n_1n_2n_2$ 3 : 1	$n_1n_1N_2n_2$ 3 : 1	$n_1n_1n_2n_2$ 0 : 1

It will be apparent from the above that only one-sixteenth of the population with the genotypic constitution $n_1n_1n_2n_2$ will breed true for branched earheads;

four-sixteenths with the genotypic constitution of $N_1n_1N_2n_2$ will segregate on a 15 : 1 basis; four-sixteenth with either $N_1n_1n_2n_2$ or $n_1n_1N_2n_2$ will segregate on a 3 : 1 basis, while all the other genotypes will bear normal, unbranched ears. All the expected genotypes have been realized in the cross under consideration.

As has been mentioned in the introductory chapter of this paper, the branching character was invariably restricted to the lower half of the ear and only a few ears and not all exhibited this peculiarity in each plant. If the genetic constitution of the plants producing branched earheads was such as to favour the development of branched ears alone, it may reasonably be argued as to why some ears only and not all should develop this characteristic. The difference between normal and branched ears in the same plant may possibly be attributed to differences in metabolism or to cytological disturbance at the growing point. In this connection it may be pointed out that Kempton [1923] observed in maize that the variability in branching cannot be attributed to the influence of hereditary modifying factors and must be considered as a phenomenon of expression rather than of transmission. This author impresses the view that the mode of inheritance of branched ears is characteristic of a large class of characters which seem so delicately balanced as to require some special conditions in ontogeny for complete expression and that internal developmental factors, quite aside from external influences, play a large part in the expression of structural characters. It may be acknowledged, however, that the absolute reason why all ears in the same plant do not develop this character of branched ears is a matter worth further investigation, and it is proposed in the future to study the matter from a cytological standpoint.

Summary

The inheritance of branched ears in barley was observed to depend on duplicate factors in a cross between Chevalier (2-rowed) and Pusa Type 21 (6-rowed) barleys. Neither the parents nor the F_1 showed this characteristic which made its appearance only in F_2 and the succeeding generations. The factors for branched ears segregated independently of the factors responsible for the inheritance of fertility of the earhead.

REFERENCES

Biffen, R. H. (1916) . . . *J. Gen. 5*, 225-228.
Bose, R. D. (1931) . . . *Ind. J. Agric. Sci. 1*, 58-89.
Collins, G. N. (1917) . . . *J. Agric. Res. 9*, 383-395.
Kempton, J. H. (1923) . . . *J. Hered. 14*, 243-251.
Kezer, A., and Bryak, B. (1918) . *Colorado Agric. Exp. Sta. Bull. 249*, 1139.
Koernicke, F. (1882) . . . *Zeits. f. d. gesamte Bauwesen, Leipzig.*
Meunissier, A. (1918) . . . *Bull. Soc. Nat. Acclimat*, 1-31.
Nelsson-Leissner, G. (1925) . . *Hereditas. 7*, 1-74.
Rimpau (1899) . . . . *Landw. Jahrb.* 1891. D. L. Pr. 1899 Nr. 79.
Schneider, F. (1913) . . . *Z. Pflanzenz.* 1, 301-322.
Tschermak, E. (1910) . . . *Fruwirth. Zucht. Landw. Kulturpfl.* 4, 293.
——————— 1923) . . . *Fruwirth's Handbuchder Landwirt. Pflanz. Zuch.* 4.
Wittmack, L. (1871) . . . *Verh. d. bot. ver. d. Prov. Brandenburg. Jahrg.* S, *142*.

OIL FORMATION IN GROUNDNUT WITH REFERENCE TO QUALITY

BY

J. S. PATEL, M. Sc. (Cornell), Ph.D. (Edin.),

Oil Seeds Specialist, Madras,

AND

C. R. SESHADRI, B.A., B.Sc. Ag.,

Assistant to the Oil Seeds Specialist

(Received for publication on 9th October 1934)

(With two text-figures)

I. Introduction

The Ottawa Trade Agreement has secured for India a preference of ten per cent. on the imports of Indian groundnut into the United Kingdom. The area under groundnut in West Africa has been increasing for the past ten years as a result of which competition between the West African and the Indian groundnut is getting keener.

Both the Empire Marketing Board and the Indian Trade Commissioner have drawn attention to the necessity of improving the quality of the Indian groundnut, particularly that of Madras. In point of view of quality the Indian groundnut must contain more of oil and less of free fatty acid than it does at present. The Empire Marketing Board has investigated the free fatty acid content of the samples of Indian groundnuts collected from the shipments to Europe during the two months, December 1926 and January 1927. A summary of the results of the investigations of the Empire Marketing Board is given in Table I.

TABLE I

Free fatty acid content of Indian groundnut kernels on arrival at European ports

Ports of shipment	December 1926 shipments*		January 1927 shipments*	
	Average free fatty acid content per cent	Range of free fatty acid content per cent	Average free fatty acid content per cent	Range of free fatty acid content per cent
Madras (*a*)	4·21	1·09—9·06	4·13	1·0—10·2
Pondicherry (*a*)	2·52	1·83—3·82	4·10	1·4— 8·7
Vizagapatam (*a*)	2·55	0·96—2·86	3·00	1·8— 3·2
Bimlipatam (*a*)	1·70	0·90—3·16	..	..
Coconada (*a*)	0·98	0·93—1·08	..	..
Cuddalore (*a*)	..	..	9·32	7·9—11·1
Negapatam (*a*)	..	..	8·44	5·0—11·6
Bombay (*a*)	1·32	0·65—2·26	1·55	0·9— 2·2
Murmagoa (*a*)	1·87	0·99—2·22	1·42	0·7— 2·6
Calicut (*a*)	7·94	3·60—12·25	5·00	3·8— 6·5
Bombay (*b*)	0·83	0·48—1·77	1·33	0·7— 3·0
Murmagoa (*c*)	2·25	0·93—3·09	1·77	1·6— 1·9

(*a*) Groundnut from Madras
(*b*) Groundnut from Bombay
(*c*) Groundnut from Khandesh

* The shipments in December 1926 and January 1927 amounted to 33,750 tons and 49,700 tons, respectively.

The Indian Trade Commissioner, London, remarks "If you take the Madras kernels as containing on an average four per cent of free fatty acids, you have a charge of about £2-10 per ton of oil for extraction and a loss of £14 in the sale of free fatty acids, as compared with the price obtained from the refined oil. Taking Madras exports at 300,000 tons of kernels annually, the cost of extracting free fatty acid amounts to about £300,000 and the loss compared with refined oil adds another £84,000 making nearly £400,000 lost in all".

An investigation into the causes which affect the quality of groundnut was therefore, taken up. The present investigation deals with the rate of oil formation in groundnut and the effect of early harvest on the quality of the produce. The effect of storing damp or moist kernels is under investigation and will form the subject of a separate paper.

II. Materials

The groundnut is a self-fertilized crop. The flower buds which are in the calyx in the evening, emerge by degrees and in the early morning the anthers burst and pollinate the stigma. Fertilization is complete before midday is past; the flower droops in the evening and withers completely in three days. The stalk of the ovary elongates and the gynophore is visible in about five to seven days after fertilization. The geotrophic gynophore, with the ovary, at its tip pierces the ground to a depth of two to five centimetres, and the ovary which has remained dormant till then begins to develop. This process requires two or three weeks after the opening of the flower, depending upon the position of the flower in the axis. For complete development of pod, it takes about sixty days from the time of fertilization.

A bunch groundnut of the Spanish type, locally known as Gudiyattam bunch, was utilized in the present investigation. About 10,000 flowers were marked by wire wickets. To mark the flowers blossoming on different dates, differently coloured wickets were used. After the 'pegs' (gynophore) began to appear, the threads which were tied to the flower were transferred to the respective gynophores. As the number of pegs that could be marked in this way was small and as the maximum percentage of fertilization was only forty-two, pegs showing similar state of development were also tagged to provide requisite material of uniform development. It was soon discovered that the kernels obtained from the flowers which opened on the same day were not uniform in their development since the pegs which developed nearer the ground entered the earth earlier and therefore produced kernels of relatively greater maturity. It was, therefore, found necessary to select those kernels which exhibited the same degree of maturity from the material harvested at various intervals.

The pods were harvested for the first time on the twenty-fifth day after flowering and the harvests were continued at intervals of a week up to the sixtieth day after flowering. Corresponding to these six harvests, six distinct stages in the development of the pods were obtained. A brief description of each of these six stages is given below:

Stage 1.—Pods obtained on the twenty-fifth day after flowering have a size of 0·5 to 1·5 cm. Shell is very fleshy and contains plenty of moisture. Kernels 2 to 3 mm. long are embedded in the fleshy mass. "Beak-end" kernel has not yet been formed.

Stage 2.—Pods on the thirty-second day after flowering are 0·75 to 2 cm. long but the shell is still fleshy. The kernels of one-seeded pod measure about 0·75 cm. in length. The " beak-end " kernel has just developed.

Stage 3.—Pods on the thirty-ninth day after flowering measure 1 to 2 cm. in length. The " stalk-end " portion of the shell is no longer fleshy but the " beak-end " portion is still fleshly. Kernels show traces of pigmentation. The " stalk-end " kernel in the two-kernelled pods is 0·75 to 1 cm. in length. The " beak-end " kernels are 0·3 to 0·5 cm. in length.

Stage 4.—Pods harvested on the forty-sixth day are from 1 to 2·5 cm. in length. Air space is observed between the kernel and the shell. Shells show papery lining. " Beak-end " kernels show traces of pigmentation and they have developed up to a length of 0·75 cm.

Stage 5.—Pods on the fifty-third day after flowering have developed up to 1 to 3 cm. in length. The air space between the shell and the kernels is increased. The white papery lining gradually disappears. The pigment on the kernel is marked.

Stage 6.—The lining of the shells of pods on the sixtieth day after flowering is discoloured. Kernels have hardened and the pigmentation on the testa is intensified.

The pods were removed to the laboratory immediately after harvest and washed and were dried by gently rolling them in a blotting paper.

III. Shelling percentage

The pods were shelled and the shelling percentages were determined for fresh materials before drying. The shelling percentage is expressed as the weight of kernels when the weight of the whole pods is taken as hundred.

From Table II where the shelling percentages for various stages of development are given, it is clear that the kernel develpes most rapidly between the thirty-ninth and forty-sixth day after flowering. Before and after that period the rate of increase in the shelling percentage is comparatively slow (Fig. 1).

Table II

Shelling percentages at various stages

Stage	2	3	4	5	6
No. of days after flowering .	32	39	46	53	60
Shelling percentage . .	6·6	17·3	54·9	66·3	72·9

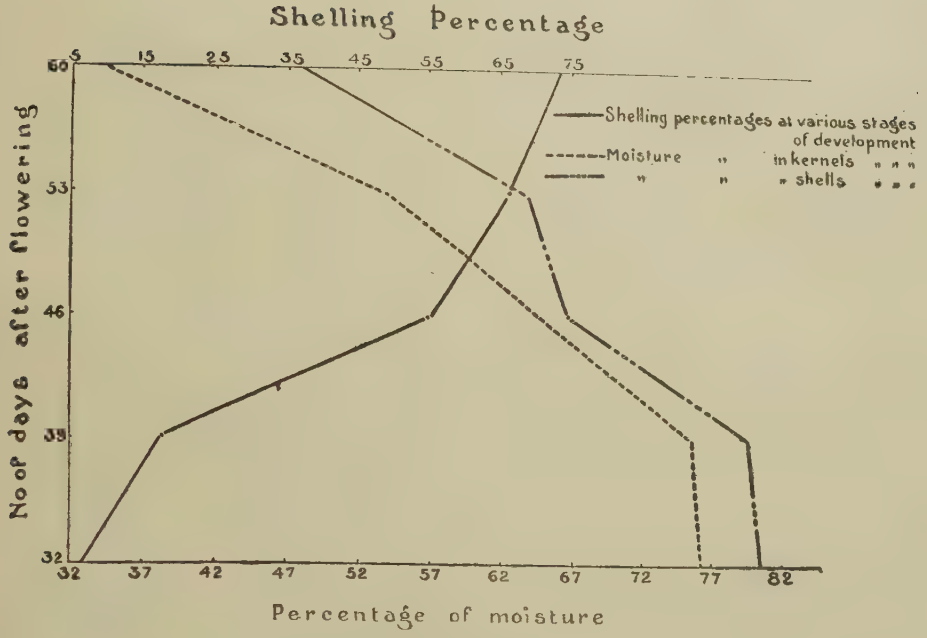


Fig. 1. Shelling percentage

IV. Moisture content

The moisture content of shells and kernels was determined by drying the samples in an oven at 98°C. in partial vacuum. This method does not give an indication of the absolute moisture content but it gives sufficient information to enable relative comparison.

In Table III the percentage of moisture in shells and kernels at various stages of the development are shown. It is observed that, in all the stages, the moisture content is higher in shells than in kernels. This indicates that a moisture gradient exists between the shells and the kernels, and that the transfer of moisture from the shells to kernels goes on throughout the development of the pod. The moisture content of both the shells and the kernels gets reduced as the pods mature (Fig. 1). That even mature kernels contain as high as thirty-three per cent. moisture is a fact which should not be lost sight of.

TABLE III

Percentage of moisture at various stages

Stage	2	3	4	5	6
No. of days after flowering	32	39	46	53	60
Moisture in shells	80·4	79·4	66·1	63·2	48·1
Moisture in kernels	76·2	75·5	65·0	53·9	33·9

V. OIL CONTENT

The oil content was determined for both the fresh and dried kernels. For the latter the material obtained after determining the moisture content was utilized. The oil was extracted with petroleum ether, using glass soxhlet apparatus and fat-free thimbles. The first extraction was taken to have been complete after the ether had been siphoned seven times. After completely drying the thimble containing the material, in an oven, the partially extracted material was re-ground and re-extracted until six siphonings were complete. The process was throughout controlled by duplicate samples.

It is evident from Table IV that the synthesis of oil goes on continuously and that both in the beginning and the end it is rather slow. The most rapid accumulation of the oil takes place during the fortnight commencing with the thirty-second day after flowering (Fig. 2).

TABLE IV

Percentage of oil in kernels at various stages

Stage	1	2	3	4	5	6
No. of days after flowering	25	32	39	46	53	60
Oil in fresh kernels	0·35	3·58	5·87	8·35	19·75	30·94
Oil in dried kernels	4·27	12·31	23·48	38·28	43·86	48·51
Rate of increase in oil per week	..	8·04	11·17	14·80	5·58	4·65

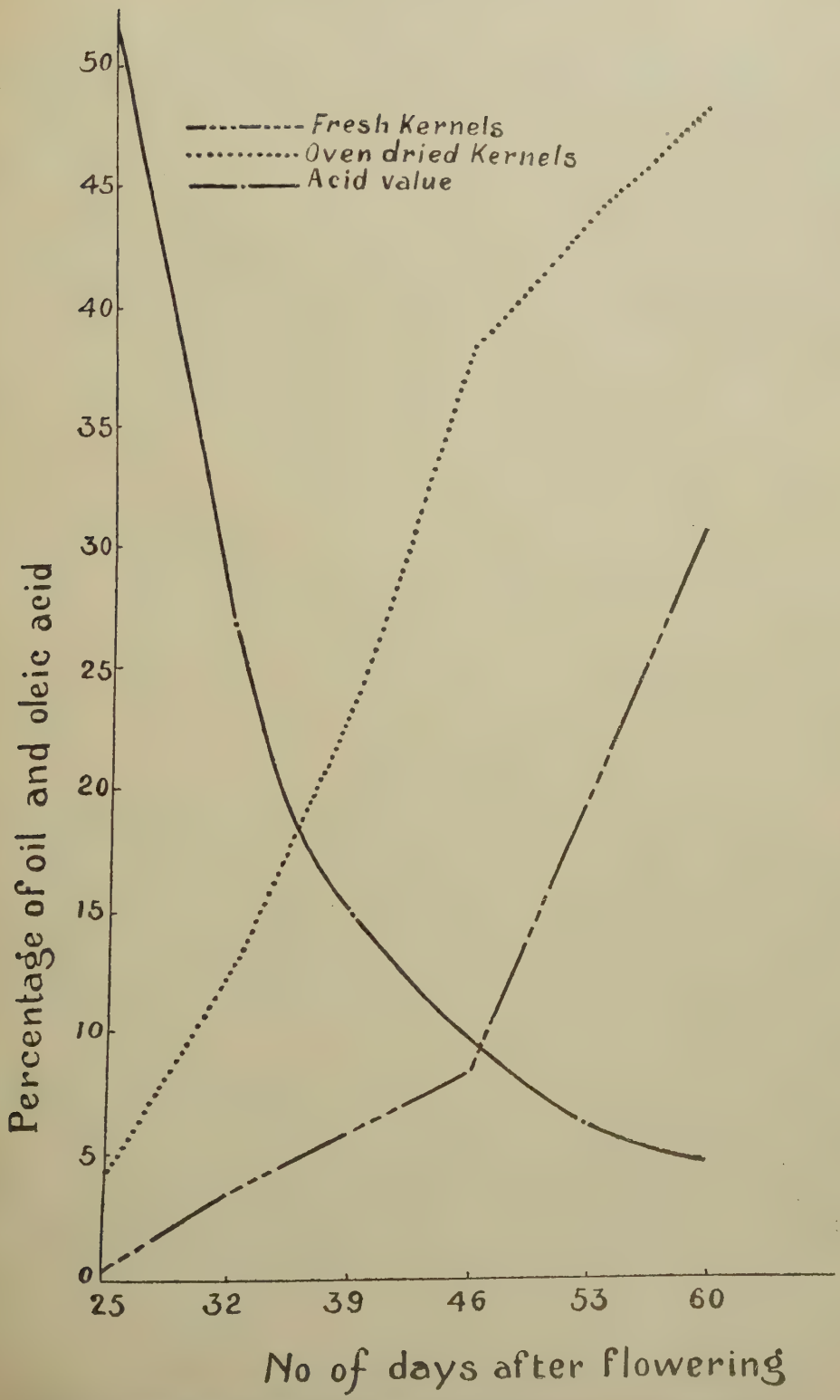


Fig. 2. Percentage of oil and acid value at different stages of groundnut kernels

VI. Acid value

To the flask containing oil extracted from the fresh sample, about 20 c.c. neutral 95 per cent. alcohol were added, and the flask immersed in a water-bath and agitated at intervals so as to dissolve the free fatty acids completely. The hot fluid was titrated with $N/10$ sodium hydroxide using phenolphthalein as indicator. The results have been expressed as percentage of oleic acid in 100 grms. of oil taking one c.c. of $N/10$ sodium hydroxide as equal to 0·028 grm. of oleic acid.

In Table V the acid value of oil at various stages of development of the seed is given. The figures show that the percentage of free fatty acid decreases as the seed matures. This reduction of the free fatty acid is more rapid during the twenty-fifth and thirty-ninth day after flowering (Fig. 2).

Table V

Free fatty acid content in kernels

Stage	1	2	3	4	5	6
No. of days after flowering .	25	32	39	46	53	60
Acid value expressed as oleic acid	51.45	26.62	14.72	9.87	6.28	5.07
Reduction in the acid value per week	..	24.83	11.90	4.85	3.59	1.21

VII. Discussion

Eyre [1931] has shown, in the case of linseed, that the oil accumulates rapidly during the early stages of the development of the seed after which further increase is comparatively slight. In the case of groundnut, however, the accumulation of the oil in the seed is rather slow both in the initial and the final stages of the development of the seed. Sahasrabuddhe and Kale's [1933] investigations on niger seed show : (*a*) that the formation of oil is most rapid in the early stages, (*b*) that the oil is formed from carbohydrates which are converted into free fatty acids by some enzymes, and (*c*) that the oil is transformed from the accumulated free fatty acids by enzymes.

The results of the present investigation are in agreement with the view that, in initial stages in the development of the seed, there is preponderance of the free fatty acid and that, in the final stage, the quantity of free fatty acid is considerably reduced and the quantity of oil is increased.

In Madras, there are two main cultivated varieties of groundnut, *viz.*, ' Local Mauritius ' and ' Gudiyattam bunch'. The former ripens in about 130 days after

sowing and the latter in about ninety-five days. This period varies to the extent of fifteen to twenty-five days, depending on the soil and climatic conditions. Both the varieties flower in three to four weeks after sowing and the flowering continues till about three to four weeks before the harvest. It is, therefore, natural to find, at the time of harvest, a number of undeveloped pegs which have not entered the soil or entered the soil just prior to the harvest. At the time of the harvest, the pods are found to be in different stages of maturity, some entirely immature, while the others are partially mature. The produce therefore consists of a majority of mature kernels and the remaining partially mature or immature kernels which reduce the percentage of oil from the sample and increase the free fatty acid content. In Table VI the results of counts from 500 plants, of undeveloped pegs, tender nuts, immature nuts, and mature nuts of the two varieties are given. The figures are the averages of 500 plants pulled out at the time of harvest in different years, and these illustrate the proportion of immature kernels in the bulk produce.

TABLE VI

Results of '500 plant studies' in groundnut varieties 1930-33 rain-fed seasons

(Averages of 500 plants pulled out and counted at harvest time)

Name of variety	Year	Undeveloped pegs	Tender nuts	Immature nuts	One-kernelled pods	Two-kernelled pods	Good nuts	Total kernels	Grand totals
Local Mauritius	1930	3·27	1·46	1·49	2·906	14·064	17·00	31·09	24·29
	1931	2·814	5·708	2·816	2·306	8·352	10·974	19·74	22·33
	1932	3·722	3·962	1·894	3·252	11·148	14·35	25·44	23·26
	1933	3·904	2·344	1·618	2·054	12·708	14·78	27·36	22·75
Gudiyattam bunch	1930	3·222	3·846	1·922	1·358	6·304	7·11	13·492	16·068
	1931	4·618	5·622	1·578	1·62	3·614	5·214	8·912	17·06
	1932	3·16	2·294	1·648	2·76	8·76	11·20	19·92	18·10

Apart from the lack of uniform maturity, there is also another factor which affects considerably the free fatty acid and the oil content of the sample. In many districts, particularly in those where the bunch type of groundnut is grown, the cultivator harvests the crop from one to two weeks before maturity, as he is afraid of the pods germinating in the soil and his not being able to enter the fields after heavy rains. The produce from such early harvests is inferior in quality. From Table I it may be noticed that the shipments from Calicut are the worst and contain as much as five to eight per cent of free fatty acids. The shipments from Calicut are mainly the groundnuts from Pollachi area where almost every year the crop is harvested either too early, or it is found not practicable to dry the produce properly on account of the rains. The early harvested groundnuts are generally very damp and, if not dried rapidly and properly, are liable to fermentation which increases the free fatty acid content and reduces the quantity of oil. The problem can, however, be met by cultivating a variety of even shorter duration than the ordinary bunch. Attempts are being made to evolve such a variety.

VIII. Summary and conclusions

As the groundnut seed develops, the percentage of oil gradually increases except in the early stages immediately following blooming and the period just preceding maturity. There is, throughout the development of the seed, a gradual and uniform gain in oil content and reduction in the free fatty acid content. The moisture content of the seed diminishes and the shelling percentage increases as the seed develops.

The harvest of groundnut even one week before the kernels are fully ripe, increases the quantity of free fatty acid and reduces the oil content of kernels by about five per cent. It is suggested that one of the reasons for the poor quality of South Indian groundnuts is the practice of harvesting groundnuts before they are fully mature. This practice not only increases the proportion of immature kernels but also increases the period required for drying the produce, and thus increases the chances of deterioration of the produce through fermentation which would be accelerated when the produce is wet.

The authors are indebted to Mr. V. Ramanatha Ayyar, the Cotton Specialist, for affording facilities to grow at his station the material required for the present investigation.

REFERENCES

Eyre, J. V. (1931). *Bio-Chem. J.* **25**, 1902.
Sahasrabuddhe, D. L. and Kale, N. P. (1933). *Ind. J. Agric. Sci.* **3**, 57.

INHERITANCE OF CHARACTERS IN *SETARIA ITALICA* (BEAUV.), THE ITALIAN MILLET

PART VII.—PLANT PURPLE PIGMENTATION

BY

G. N. RANGASWAMI AYYANGAR, B.A., I.A.S.,

Millets Specialist, Agricultural Research Institute,

T. R. NARAYANAN, B.Sc. Ag.,

T. NARAYANA RAO, M.A.,

AND

P. SESHADRI SARMA, B.Sc.Ag.,

Assistants, Millets Breeding Station, Coimbatore

(Received for publication on 9th January 1935)

(With Plates XI-XIII)

There are many varieties of the Italian millet distinguishable by their grain colours. Amongst varieties with the same grain colour separation is possible through bristles and earhead shapes. But at a breeding station where the whole life of the plant is being watched, a further grouping of the plants in the pre-maturity stages is possible. Apart from plant and leaf habits, purple pigmentation is the most striking character in the varietal grouping.

Plants of the Italian millet are broadly divisible into those with, and those without, purple pigmentation. A plant without purple pigmentation is called non-pigmented (No-P).

Plants with purple pigmentation fall into six classes according to the depth, distribution and mode of manifestation of the purple pigment on the plant. Seedlings give a general clue to the pigment classes. For this purpose seedlings of over 700 pure lines were examined and the development of pigmentation throughout the growing period for each of the various classes was observed during five seasons on 57 individual plants.

The lowest manifestation of purple pigmentation is in the last class designated P_6. The manifestation is so sparse that there is a risk of this being passed for a non-pigmented type. The seedlings of this P_6 are green. In the adult plant, the leaf-blade is occasionally coloured light purple. But the place to look for the

PLATE XIII.

SETARIA ITALICA, (BEAUV.)

Pigment class—P_5

SETARIA ITALICA, (BEAUV.)

Pigment class—P_2

SETARIA ITALICA, (BEAUV.)

Pigment class—P_1

faint pigment is the earhead, a careful examination of which will show traces of purple pigment on the peduncle, on a few glumes and on stray bristle-tips. This pigmented class is best studied in the milky stage and the place to look for pigment is the edge of the glume. This class is characterised by light pigment in the earhead only and a late manifestation thereof.

The next class is P_5. In this class also the seedlings are green like P_6, and again the manifestation of the pigment is best at the flowering stage. The vegetative parts then take on a light purple colour and the earhead (the reproductive parts) appears a good purple. The light purple of the vegetative parts shows in the exposed roots, leaf-sheaths, leaf blades, nodes, and inter-nodes in a sparse manner and inconstantly. In the exposed roots, leaf-sheaths, leaf-blades and nodes, even this sparse colour can be detected only when the earhead ripens. This class is characterised by a dilute body pigment and a normal head pigment, both manifested late in the plant's life (Plate XIII).

P_6 and P_5 have this in common that the seedlings are green, and that the manifestation of purple pigmentation in both of them is late in the life of the plant.

The next four classes—P_4, P_3, P_2 and P_1—give indications of the presence of purple pigmentation in the seedling stage.

In P_4 the seedlings betray traces of light purple on their leaf-sheaths. In the adult plants the exposed roots and leaf-sheaths are light purple, the rest of the vegetative parts remaining green. In the earhead there is a sparse manifestation of light purple on odd glumes and bristle tips. This class is characterised by light purple seedlings. The manifestation of pigmentation is confined to some vegetative parts and is light in the reproductive parts.

The next class is the P_3. This class is a more steady and accentuated form of P_4. The seedling pigmentation is more easily recognised. The vegetative parts manifest light purple in all places, and the reproductive parts are also light purple. This class can be described as light purple throughout.

P_4 and P_3 have this in common, that the purple pigmentation is manifested lightly, but in P_4, the manifestation is restricted to some places only.

In the next two classes P_2 and P_1, the seedlings are distinctly purple. In the adults of P_1, there is a greater depth of purple in both the vegetative and the reproductive parts.

In the P_2 class the pigmentation is similar to the P_1 but there is a dilution on the reproductive parts, the pigmentation being sparse in the peduncles, glumes and bristles. The P_2 can be characterised as all purple with a dilution in the earhead (Plate XII).

The P_1 class is purple throughout and stands out as the best manifestation of purple pigmentation in the Italian millet (Plate XI).

Descriptions of the six types of pigment (P_1 to P_6) both as seedlings and as adults, are tabulated below :—

TABLE I

Seedlings

Pigment class	Exposed roots	Leaf sheaths	Leaf blades	Junction of leaf sheath and blade
P_1	Purple	P	P (stray)	P
P_2	Purple	P	P (stray)	P
P_3	Light purple	LP	LP (stray)	LP
P_4	Green	LP (stray)	G	G
P_5	Green	G	G	G
P_6	Green	G	G	G

TABLE II

Adults (vegetative parts)

Pigment class	Exposed roots	Leaf sheaths	Leaf blades	Junction of leaf sheath and blade	Nodes	Internodes
P_1	P	P	P (stray)	P	P	P
P_2	P	P	P (stray)	P	P	P
P_3	LP	LP	LP (stray)	LP	LP	LP
P_4	LP	LP (stray)	G	G	G	G
P_5	LP (stray)	LP (stray)	LP (stray)	G	LP (stray) when ripe	LP (stray) when ripe
P_6	G	G	LP (stray)	G	G	G

TABLE III
Adults (earheads)

Pigment class	Peduncles	Glumes	Bristles	Remarks
P_1	P	P	P	
P_2	P (stray)	LP (stray)	LP (stray)	Risk of passing for P_1.
P_3	LP (stray)	LP	LP	Risk of passing for P_1.
P_4	LP (stray)	LP (stray)	LP (stray)	Risk of passing for P_6.
P_5	P	P	P	Risk of passing for P_1 (when ripe).
P_6	LP (stray)	LP (stray)	LP (stray)	Risk of passing for No-P.

These six classes of pigmentation are distinct and with sufficient care and experience easily recognised. Pure lines of all the six types have been isolated and are breeding true.

The six pigmented classes differ obviously from the non-pigmented in having the basic factor (**P**) for pigmentation. P_1 and P_2 express clear purple pigmentation even in the seedling stages ; P_3 and P_4 also do so, but in a dilute degree. The seedlings of P_5 and P_6 are apparently green and develop pigmentation late in the life of the plant and that dilutely.

A factor (**I**) which determines the intensity with which pigmentation manifests itself, is present in P_1, P_2 and P_5, and absent in P_3, P_4, and P_6, and accounts for differential depths of manifestation of the purple pigment.

Purple pigmentation, whether intense or dilute, is also localised. Such pigment may be present in all the parts at which it could be present, or be localised in either the vegetative or earhead parts. A factor **V** determines clear manifestation in vegetative parts and a factor **H**, clear manifestation in the earhead. When both **V** and **H** are present, the pigmentation is general in distribution. **V** determining expression in vegetative parts, its presence shows right from the seedling stage and helps to mark off the seedlings of P_1, P_2, P_3 and P_4 from those of P_5 and P_6.

The interactions of **P, I, V** and **H** factors produce the diversity of forms characterizing varieties of this millet*. The nature and constitution of the six pigmented and the non-pigmented classes are given below :—

P_1—Has all the four factors and is a pigmented type of the highest degree (**PPVVHHII**).

P_2— Lacks the **H** factor, **V** and **I** being present. The absence of **H** results in a sparse and inconstant distribution of the pigment in the earhead

*Recent work on ' Genetics of Millets in India ', by G. N. Rangaswami Ayyangar, *Madras Agric. J.*, Vol. XXII, No. 1, P. 23. Paper contributed to the Symposium on ' Recent Work on Plant Genetics in India ', at the Indian Science Congress, Bombay, January 1934, Dr. P. S. Hudson, Deputy Director, Imperial Bureau of Plant Genetics, Cambridge, opening the discussion.

giving the head an almost greenish look when emerging (**PPVVhhII**).

P_3—Is like P_1 in distribution, but lacking the **I** factor, does not manifest the pigmentation in intensity. It is a P_1 dilute (**PPVVHHii**).

P_4—Has the **P** and **V** factors only; lacks **I** and **H**. The resultant type is practically a green earhead on a dilute purple pigmented vegetation (**PPVVhhii**).

P_5—Has **P, H** and **I** factors. The factor **V** is absent. This produces a good purple pigmented earhead, on a practically green vegetation (**PPvvHHII**).

P_6—Is the type with the sparsest pigment. Its earheads show traces of purple. Being an extreme recessive its genetic constitution will vary according to which class it is allelomorphic, but and resultant expression of extreme sparseness in pigmentation is constant. (**PPvvHHii**), or (**PPvvhhII**), or (**PPvvhhii**).

No-P—Varieties that are non-pigmented will have the following wide range of genetic constitutions, whose nature will not become evident until they are mated with pigmented types or have been extracted from pigmented allelomorphs. (**ppvvhhii, ppVVhhii, ppvvHHii, ppvvhhII, ppVVHHii, ppVVhhII, ppvvHHII,** or **ppVVHHII**).

A number of pure lines isolated and studied, and crosses purused at the Millets Breeding Station, Coimbatore, confirm the above analysis and are presented below :—

TABLE IV

Pure for **P, V, H** *and segregating for* **I**
Segregating for pigment classes P_1 *and* P_3

Season	Generation and family	Character of selection and constitution	Segregating for	
			P_1	P_3
1927	Natural cross			
1928	F_2 *S. I.* 758 . .	P_1 (**PPVVHHIi**) . .	57	20
1930	F_3 *S. I.* 1375 to 1379, 1382	P_1 (**PPVVHHII**) . .	Pure	..
	S. I. 1374, 1380, 1381	P_1	512	181
1931	F_4 (from *S. I.* 1374)			
	S. I. 1971, 1972 .	P_1	Pure	..
	S. I. 1970, 1973 to 1975.	P_1	402	136
	S. I. 1976, 1977 .	P_3 (**PPVVHHii**) . .	..	Pure
		Total .	971	337
		Expected .	981	327

$\chi^2 = 0{\cdot}41$ $P > {\cdot}5$

TABLE V

Pure for **P** *and* **V**, *segregating for* **H** *or* **I**

Segregating for pigment classes P_5 *and* P_6

Season	Generation and family	Character of selection and constitution	Segregating for P_5	Segregating for P_6
1927	Natural cross			
1928	F_2 *S. I.* 940 . .	P_5 (PPvvHhII) or (PPvvHHIi.	212	74
1930	F_3 *S. I.* 1521, 1522, 1525, 1530.	P_5 (PPvvHHII) . .	pure	..
	S. I. 1523, 1524, 1526, to 1529, 1531 to 1533.	P_5	785	23
	S. I. 1534 to 1538 .	P_6 (PPvvhhII) or (PPvvHHii).	..	pure
1931	F_4 *S. I.* 1990 . .	P_6	..	pure
		Total .	997	310
		Expected .	980	327

$\chi^2 = 1\ 14 \quad P > \cdot 2.$

Other experiences

1928	*S. I.* 941 clan.			
	S. I. 941 . . .	P_5	228	78
1929	*S. I.* 888 clan.			
	S. I. 1206, 1208 . .	P_5	400	122
	S. I. 1207, 1209 . .	P_5	pure	..
	S. I. 1210 . . .	P_6	..	pure
		Total .	628	200
		Expected .	621	207

$\chi^2 = \cdot 32 \quad P > \cdot 5$

TABLE VI

Pure for **P, V, I** *and segregating for* **H**

Segregating for pigment classes P_1 *and* P_2

Season	Generation and family	Character of selection and constitution	Segregating for	
			P_1	P_2
1931 (summer)	Artificial crosses . .	*S. I.* 1849 P_2 (PPVVhhII)		♀
	LXXV to LXXVII .	*S. I.* 381 P_1 (PPVVHHII)	♂	
1931 (rain-fed)	F_1	....	F_1	..
1932	F_2			
	S. I. 2264 to 2269 .	P_1 (PPVVHhII) . .	1033	369
		Total .	1033	369
		Expected .	1052	351

$\chi^2 = 1 \cdot 30$ $P > \cdot 2$

Other experiences

1928	*S. I.* 942 *clan.*			
	S. I. 1248, 1823, 1825, 1828, 1830, 1832, 1845, 1847, 1848.	P_1	1539	518
	S. I. 1249, 1827, 1829, 1833, 1834, 1843, 1844, 1846.	P_1	Pure	..
	S. I. 1849, 1850 .	P_2	..	Pure
		Total .	1539	518
		Expected .	1543	514

$\chi^2 = \cdot 04$ $P > \cdot 8$

TABLE VII

Pure for **P, V, i**, *and segregating for* **H**

Segregating for pigment classes P_3 *and* P_4

Season	Generation and family	Character of selection and constitution	Segregating for	
			P_3	P_4
1925	Natural cross . .	....	..	..
1926	F_2 *S. I.* 269 . .	P_3 (PPVVHhii) . .	P_3 and P_4 (no counts).	
1928	F_3 *S. I.* 392, 393, 395 to 399, 401 to 404, 406, 407.	P_3 (PPVVHHii) . .	Pure	..
	S. I. 394, 400, 405, 408.	P_3 . . .	322	84
	S. I. 387, 388, 391 .	P_4 (PPVVhhii) .	..	Pure
1930	F^4 (from *S. I.* 405.)			
	S. I. 1317, 1321, 1322, 1325, 1329.	P_3	Pure	..
	S. I. 1318 to 1320, 1323, 1324, 1326, 1327.	P_3	448	140
	S. I. 1328 . .	P_4	..	Pure
1931	F_5 (from *S. I.* 1320).			
	S. I. 1966 . .	P_3	Pure	..
	S. I. 1962 to 1965, 1967.	P_3	229	90
	S. I. 1968, 1969 .	P_4	..	Pure
		Total .	999	314
		Expected .	985	328

$\chi^2 = 0{\cdot}81$ $P > {\cdot}3$

TABLE VIII

Pure for **P**, **H** *and* **I**, *segregating for* **V**.

Segregating for pigment classes P_1 *and* P_5

Season	Generation and family	Character of selection and constitution	Segregating for	
			P_1	P_5
1927	*S. I.* 296 *clan.*			
	S. I. 915, 916, 1224, 1226	P_1 (PPVvHHII) . .	814	271
1928	*S. I.* 756 *clan.*			
	S. I. 1094, 1095 .	P_1	318	116
1928	*S. I.* 942 *clan.*			
	S. I. 1824, 1826, 1831 .	P_1	618	174
		Total .	1750	561
		Expected .	1733	578

$\chi^2 = \cdot 66$ $P > \cdot 3$

TABLE IX

Pure for **P, H** *and* **i**, *and segregating for* **V.**

Segregating for pigment classes P_3 *and* P_6

Season	Generation and family	Character of selection and constitution	Segregating for	
			P_3	P_6
1922	Natural cross . .	....	..	..
1925	F_2 *S. I.* 85 . .	P_3 (**PPVvHHii**) . .	P_3 and P_6 (no counts)	
1926	F_3 *S. I.* 204. . .	P_3 (**PPVVHHii**) . .	Pure	..
	S. I. 203, 208 . .	P_3	384	85
	S. I. 205 to 207 .	P_6 (**PPvvHHii**) . .	..	Pure
1928	F_4 (from *S. I.* 203).			
	S. I. 323 . .	P_3	Pure	..
	S. *I.* 324 to 338 .	P_3	1477	536
	S. I. 339 to 354 .	P_6	..	Pure
	F_4 (from *S. I.* 208) . *S. I.* 364 . .	P_6	..	Pure
1929	F_5 (from *S. I.* 326) .			
	S. I. 1053, 1055 .	P_3	Pure	..
	S. I. 1054 . .	P_3	174	58
	S. I. 1056 . .	P_6	..	Pure
		Total .	2035	679
		Expected .	2036	679

$\chi^2 = \cdot 0005$ $P > \cdot 98$

TABLE IX—*contd.*

Season	Generation and family	Character of selection and constitution	Segregating for P_3	Segregating for P_6
	Other experiences			
1927	*S. I.* 742 *clan.*			
	S. I. 742, 993 to 995, 997, 999, 1001 to 1004.	P_3	1465	478
	S. I. 996, 998, 1000 .	P_3	Pure	..
	S. I. 1005 to 1008 .	P_6	..	Pure
1928	*S. I.* 746 *clan.*			
	S. I. 746, 1074 to 1078, 1741, 1742.	P_3	1222	394
	S. I. 1079, 1743, 1744	P_3 . . .	Pure	..
	S. I. 1080 to 1082, 1745	P_6	..	Pure
1929	*S. I.* 1035 *clan.*			
	S. I. 1035 . . .	P_3 . . .	151	43
1930	*S. I.* 878 *clan.*			
	S. I. 878 . . .	P_3	123	43
		Total .	2961	958
		Expected .	2939	980

$\chi^2 = \cdot 61$ $P > \cdot 3$

In the six tables given above (Tables IV to IX) monofactorial segregations between two pigment classes are presented. In the five following tables (Tables X to XIV) are given segregations involving the pigment classes and their pigmentless allelomorphs.

TABLE X

Segregating for **P** *and pure for* **V, H** *and* **I**

Season	Generation and family	Character of selection and constitution	Segregating for	
			P_1	No-P
1928 (summer)	Artificial crosses . .	*S. I.* 181 **No-P** (**ppVVHHII**).		♀
	I to IV . . .	*S. I.* 224 P_1 (**PPVVHHII**)	♂	
1928 (rain-fed).	F_1	....	F_1	
1929	F_2 *S. I.* 1020 to 1029 .	P_1 (**PpHHVVII**) . .	1781	606
1930	F_3 (from *S. I.* 1025) .			
	S. I. 1646, 1650, 1651, 1667, 1668.	P_1	Pure	..
	S. I. 1645, 1647 to 1649, 1652 to 1654, 1657 to 1662, 1665, 1666, 1669, 1670.	P_1	1236	445
	S. I. 1655, 1656, 1663, 1664.	**No-P**		Pure
	F_3 (from *S. I.* 1026).			
	S. I. 1677 . .	P_1.	Pure	..
	S. I. 1671 to 1676, 1678 to 1681.	P_1	531	210
	S. I. 1682 to 1690 .	**No-P**	..	Pure
	F_3 (from *S. I.* 1027).			
	S. I. 1707 . .	P_1	Pure	..
	S. I. 1697 to 1706 .	P_1	639	231
	S. I. 1691 to 1696, 1708 to 1712.	**No-P**.	..	Pure
1931	F_4 (from *S. I.* 1645) *S. I.* 1997, 2001 .	P_1	Pure	..
	S. I. 1998 to 2000, 2002.	P_1	373	123

TABLE X—*contd.*

Segregating for **P** *and pure for* **V, H** *and* **I**

Season	Generation and family	Character of selection and constitution	Segregating for	
			P_1	No-P
1931	F_4 (from *S. I.* 1647)			
	S. I. 2005 . .	P_1	Pure	..
	S. I. 2003, 2004, 2006	P_1	213	83
	F_4 (from *S. I.* 1659)			
	S. I. 2032, 2033, 2036, 2042.	P_1	Pure	..
	S. I. 2031, 2034, 2035, 2037 to 2041, 2043.	P_1	743	195
		Total .	5516	1893
		Expected .	5557	1852
	$\chi^2=1{\cdot}16$	$P>{\cdot}2$		
	Other experiences			
1925	*S. I.* 76 *clan.* . .	....	..	..
	S. I. 199, 200, 317 .	P_1	719	216
	S. I. 198, 318, 319 .	P_1	Pure	..
	S. I. 201, 320 . .	No-P.	..	Pure
1925	*S. I.* 121 *clan.* . .	....	..	..
	S. I. 121, 223, 225 .	P_1	413	147
	S. I. 222, 224 .	P_1	Pure	..
	S. I. 226, 227 . .	No-P	..	Pure
1925	*S. I.* 164 *clan* . .	....	..	..
	S. I. 164, 262, 263, 265	P_1	726	250
	S. I. 260, 261, 264 .	P_1 . . .	Pure	..
	S. I. 266, 267, 268 .	No-P	..	Pure

TABLE X—*concld.*

Segregating for **P** *and pure for* **V, H** *and* **I**

Season	Generation and family	Character of selection and constitution	Segregating for	
			P_1	No-P
1928	*S. I.* 754 *clan* . .	....	..	..
	S. I. 754 . . .	P_1	54	18
1929	*S. I.* 1938 *clan.* . .	....	..	..
	S. I. 1938, 2411, 2413, 2414.	P_1	274	88
	S. I. 2412 . . .	P_1	Pure	..
	S. I. 2415 . . .	No-P	..	Pure
932	F_2 (from artificial cross)			
	S. I. 2302 to 2307 .	P_1	692	281
	S. I. 2320 to 2324 .	P_1	213	58
	S. I. 2353 to 2358 .	P_1	324	108
	S I. 2411 to 2415 .	P_1	139	52
		Total .	3554	1218
		Expected .	3579	1193

$\chi^2=2{\cdot}69$ $P>{\cdot}3$

TABLE XI

Segregating for **P** *and pure for* **V, h** *and* **I**

Season	Generation and family	Character of selection and constitution	Segregating for	
			P_2	No-P
1928	*S. I.* 942 *clan.* . .	....	..	..
	S. I. 1836, 1837, 1839, 1841, 2128, 2130, 2131.	P_2 (PpVVhhII) . .	693	204
	S. I. 1835, 1838, 1840, 2129.	P_2 (PPVVhhII) . .	Pure	..
	S. I. 2132, 2133 . .	No-P (ppVVhhII) . .	..	Pure
		Total .	693	204
		Expected .	673	224

$\chi^2=2{\cdot}44$ $P>{\cdot}1$

TABLE XII

Segregating for **P**, *and pure for* **V, H,** *and* **i**

Season	Generation and family	Character of selection and constitution	Segregating for	
			P_3	No-P
1926	Natural cross . .	....	..	..
1927	F_2 *S. I.* 707 . .	P_3 (PpVVHHii) . .	90	35
1928	F_3 *S. I.* 980 . .	P_3 (PPVVHHii) . .	Pure	..
	S. I 981 . .	P_3	77	30
	S. I. 982 . .	P_3	115	35
	S. I. 983 . .	No-P (ppVVHHii) .	..	Pure
		Total .	282	100
		Expected .	287	96
	χ^2=·28	P>·5		

TABLE XIII.

Segregating for **P**, *and pure for* **H, I** *and* **v**

Season	Generation and family	Character of selection and constitution	Segregating for	
			P_5	No-P
1927	Natural cross . .	....	..	..
1928	F_2 *S. I.* 751 . .	P_5 (PpvvHHII) . .	90	33
1929	F_3 *S. I.* 1369 . .	P_5 (PPvvHHII) . .	Pure	..
	S. I. 1370 . .	P_5	174	56
	S. I. 1371 . .	P_5	91	32
	S. I. 1372 . .	P_5	81	30
	S. I. 1373 . .	No-P (ppvvHHII) .	..	Pure
		Total .	436	151
		Expected .	440	147
	χ^2=·16	P>·5		
	Other experiences.			
1932	*S. I.* 2187 *clan* . .	....	..	..
	S. I. 2449, 2450. 2452	P_5	175	58

TABLE XIV

Segregating for **P**, *and pure for* **v**

Season	Generation and family	Character of selection and constitution	Segregating for	
			P_6	No-P
1927	Natural cross . .	....	..	..
1928	F_2 *S. I.* 747 . .	P_6 (PpvvHHii), (PpvvhhII) or (Ppvvhhii).	69	32
1929	F_3 *S. I.* 1084, 1086 .	P_6 (PPvvHHii), (PPvvhhII) or (PPvvhhii).	Pure	..
	S. I. 1083, 1085, 1087	P_6	587	196
1930	F_4 (from *S. I.* 1083) .			
	S. I. 1748, 1749 .	P_6	Pure	..
	S. I. 1746, 1747 .	P_6	350	86
		Total .	1006	314
		Expected .	990	330
	$\chi^2=1{\cdot}03$	$P>{\cdot}3$		

In the following two tables (Tables XV and XVI) segregation for **P** along with segregation for pigment classes among the purples, giving a 9 : 3 : 4 ratio are presented.

TABLE XV

Segregating for **P** *and* **H**, *and pure for* **V** *and* **I**

Season	Generation and family	Character of selection and constitution	Segregating for		
			P_1	P_2	No-P
1931 (summer)	Artificial crosses .	*S. I.* 1750 **No-P** (ppVVHHII) . .			♀
	LXXXI—LXXXIV .	*S. I.* 1849 P_2(PPVVhhII)		♂	
1931 (rain-fed)	F_1	P_1 (PpVVHhII) . .	F_1		
1932	F_2 *S. I.* 2271 to 2278 .	P_1	758	257	297
		Total .	758	257	297
		Expected (9 : 3 : 4) .	738	246	328
	$\chi^2=3{\cdot}96$	$P>{\cdot}1$			
	Other experiences				
1932	F_2 *S. I.* 2350 to 2352 . (from artificial cross)	P_1	76	24	39

TABLE XVI

Segregating for **P** *and* **V** *and pure for* **H** *and* **I**

Season	Generation and family	Character of selection and constitution	Segregating for		
			P_1	P_5	No-P
1929	Artificial crosses . .	*S. I.* 316 No-P (ppVVHHII).			♀
	XLIX—LII . .	*S. I.* 301 P_5 (PPvvHHII).		♂	
1930	F_1	....	F_1		
1931	F_2 *S. I.* 1925 to 1929 .	P_1 (PpVvHHII) . .	145	47	62
1932	F_2 (from *S. I.* 1929) .				
	S. I. 2394, 2401 .	P_1	50	12	30
		Total .	195	59	92
		Expected (9 : 3 : 4) .	195	65	87
	$\chi^2 = \cdot 84$	$P > \cdot 5$			
	S. I. 2395, 2397 . .	P_1 (PPVvHHII) .	P_1	P_5	
	S. I. 2392, 2393 . .	P_1 (PpVVHHII) .	P_1		No-P
	S. I. 2399 . . .	P_5		Pure	
	S. I. 2396, 2400 . .	P_5 (PpvvHHII) .		P_5	No-P
	S. I. 2398, 2402, 2403 .	No-P (ppVVHHII) or (ppvvHHII)			Pure
	Other experiences				
1932	*S. I.* 2187 *clan*				
	S. I. 2443, 2444, 2447.	P_1	218	69	95
1932	F_2 *S. I.* 2296 to 2301, 2308 to 2313. (from artificial cross)	P_1	1024	369	494
		Total .	1242	438	589
		Expected (9 : 3 : 4) .	1276	425	567
	$= 2 \cdot 23$	$P > 3$			

In the following table is presented the history of a clan pure for **P** and giving a bifactorial segregation for four pigment classes.

TABLE XVII

Pure for **P** *and* **I**, *and segregating for* **V** *and* **H**

Segregating for pigment classes P_1, P_2, P_5 *and* P_6

Season	Generation and family	Character of selection and constitution	Segregating for			
			P_1	P_2	P_5	P_6
1931 (summer)	Artificial crosses .	*S. I.* 1369 P_5 (PPvvHHII)			♀	
	XCVII—XCIX .	*S. I.* 1849 P_2 (PPVVhhII)		♂		
1931 (rain-fed)	F_1 . . .	P_1 (PPVvHhII) .	F_1			
1932 (summer)	F_2 *S. I.* 2186 .	P_1 . . .	P_1	P_2	P_5	P_6 (no counts)
1932 (rain-fed)	F_2 *S. I.* 2290 to 2295	P_1 . . .	338	111	108	46
1932 (rain-fed)	F_3 (from *S. I.* 2186)					
	S. I. 2431, 2433 2442.	P_1 . . .	166	58	61	29
		Total .	504	169	169	75
		Expected (9 : 3 : 3 : 1)	516	172	172	57
	$\chi^2=6{\cdot}07$	$P>1$				
	S. I. 2429 .	P_1 (PPVVHHII) .	Pure			
	S. I. 2434, 2436	P_1 (PPVVHhII) .	P_1	P_2		
	S. I. 2430 .	P_2 . . .		Pure		
	S. I. 2435, 2437	P_2 (PPVvhhII) .		P_2		P_6
	S. I. 2439 .	P_5 (PPvvHHii)			Pure	
	S. I. 2432, 2438 2440.	P_5 (PPvvHhII) .			P_5	P_6
	S. I. 2441 .	P_6 (PPvvhhII) .				Pure

The data presented in the above tables, full and elaborate as they are, were sought to be further confirmed by the following artificial crosses, in every one case obtaining an F_1 plant of the expected genetic constitution.

TABLE XVIII

Artificial crosses

Cross number	Parents		F_1s
	♀	♂	
CCLXIX, CCLXX	*S. I.* 1990 P_6 (PPvvHHii) .	*S. I.* 2133 **No-P** (ppVVhhII)	P_1
CCCIX . .	*S. I.* 364 P_6 (PPvvHHii) .	*S. I.* 268 **No-P** (ppVVHHII)	P_1
CCCXII, CCCXIII	*S. I.* 268 **No-P** (ppVVHHII) .	*S. I.* 364 P_6 (PPvvHHii) .	P_1
CCCXVI . .	*S. I.* 364 P_6 (PPvvHHii) .	*S. I.* 2133 **No-P** (ppVVhhII)	P_1
CCCXXXI .	*S. I.* 1968 P_4 (PPVVhhii) .	*S. I.* 1750 **No-P** (ppVVHHII)	P_1
CCCXXXII .	*S. I.* 1750 **No-P** (ppVVHHII)	*S. I.* 1968 P_4 (PPVVhhii) .	P_1

SUMMARY

Plants of the Italian millet are either pigmented (anthocyanic) or without purple pigment (non-pigmented). The former condition is dominant and arises by the basic presence of a factor **P**. There are various manifestations and intensities in this pigmentation. A factor **I** determines a manifestation in intensity. This is dominant to a manifestation in a weaker depth. The degree to which **P** is operative, in addition to being greatly influenced by the presence of **I**, is conditioned by two other factors **V** and **H**, which determine the alacrity with which **P** manifests in the vegetative or earhead parts. The interactions of **P**, **I**, **V** and **H** factors produce the diversity of forms characterising varieties of this millet.

Data from over 420 families are presented in support of the above hypothesis. A number of artificial crosses furnish confirmatory evidence.

NATURE OF OXIDISING PHOTO-CATALYSTS IN SOIL

BY

FAZAL-UD-DIN, B.Sc.,

Bacteriological Assistant, Agricultural Research Institute, Lyallpur

(Received for publication on 27th September, 1934)

Introduction

It has been shown quite recently by Dhar, Bhatacharya and Biswas [1933] that nitrification in soil in the tropics is more of a photo-chemical than bacterial nature. The soil is believed to act as a catalytic agent.

The catalysts in soil can be either organic or inorganic or both. Many mineral substances such as titania, zinc oxide, sodium uranate, alumina, and silica have been found to act as photo-catalysts on the oxidation of ammonium compounds [Rao and Dhar, 1931].

Silica and alumina though present in large quantities in soil have but feeble action and cannot account for the total catalytic action of the soils. In view of the alleged importance of photo-nitrification in tropical soils [*loc. cit.*] further investigation of the problem was considered desirable.

Determination of catalytic power

Appropriate amount of the substance with fifty c. c. distilled water was put in 300-c. c. Pyrex glass conical flasks in duplicate. These were plugged with cotton wool and sterilized. Mono-ethyl-amine (33 per cent solution) and aniline (pure) which were used as the test* compounds, were separately added with a sterile pipette at the rate of 0·5 c. c. per flask. The flasks thus prepared were exposed to the sun. Nitrous nitrogen was estimated by Griess Ilosvay's method. In estimating nitrous nitrogen in aniline solution, it was found necessary to add about 0·5 c. c. glacial acetic acid along with the reagent. Since the method is extremely sensitive readings less than 0·4 in half inch cell (equal to 0·001 mgm. per 100 c.c. solution) have not been considered in this paper. In the case of organic catalysts sterilization was omitted to avoid decomposition, but to check against changes due to bacterial action if any, control flasks similarly charged and wrapped in black paper were kept side by side with the exposed flasks.

* Mono-ethyl-amine and aniline were used in preference to ammonium sulphate because the latter had been found to be oxidised very slowly. It is not yet possible to say why it is so, but work is being carried on which is expected to throw some light on this point.

Experimental

In order to determine the nature of the photo-catalysts in soil, the following experiments were performed :—

I.—Catalytic action of different soils

Six soils were taken for this study :

1. Lyallpur soil (Clay loam).
2. Lyallpur soil (Loam).
3. Bara soil (Sodium soil, Barren).
4. Jhansi soil (30 per cent clay).
5. Pusa soil (33 per cent calcium carbonate).
6. Leaf mold soil.

Five grams of soil was used as a catalyst. Dark controls were also prepared and kept along side the exposed flasks. The contents of the flasks were analysed after thirteen days. The results are shown in Table I.

TABLE I

Showing the catalytic powers of various soils

Serial No.	Catalysts	Mgm. nitrous nitrogen per 100 c.c. solution	
		Aniline	Mono-ethyl-amine
1	Lyallpur soil	0·211	0·194
2	Lyallpur soil	0·058	0·376
3	Bara soil	0·275	0·233
4	Jhansi soil	trace	0·143
5	Pusa soil	0·032	0·181
6	Leaf mold soil	0·583	0·389

Another set without sterilization was also prepared and kept in the incubator at 30°C. Nitrous nitrogen was estimated after thirteen days. Bacterial oxidation of both the compounds was negligible. This however does not mean that photo-nitrification is more vigorous than bacterial process under all conditions. Under artificial conditions the nitrifying organisms are highly specific as regards their food requirements. In Omliansky's solution nitrifying organisms are well known to oxidise about five mgs. of ammonium sulphate nitrogen per 100 c. c. solution in a fortnight when incubated at 30°C., while the photo-oxidation of ammonium sulphate in the presence of soil is *nil* [Sarkaria and Fazal-ud-din, 1933] in the same period.

In another experiment the contents of the flasks similarly prepared were analysed immediately and after an exposure of two hours at noon. Except in the leaf mold soil which contained 0·006 mgm. nitrous nitrogen per ten gram soil, the amount of nitrous nitrogen present initially was negligible. There was no change in the nitrous nitrogen content of the flasks after exposure in the case of mono-ethyl-amine but in aniline flasks three soils 1, 3, and 6 gave positive nitrous reaction, not more than 1/10th of that obtained in the previous experiment.

Since the change does not take place in the dark, the reaction may well be regarded as photo-chemical; the soils seem to act catalytically is clear from a consideration of results obtained after two hours exposure.

The following conclusions may be drawn from Table I :—

1. Catalytic power varies with different soils.
2. The oxidising power of soil catalysts is different towards different compounds.
3. The catalyst in soil may be either a single substance or mixture of substances.

Since there was no dark reaction in the controls, these were omitted when working with soil constitutents.

II. Catalytic power of the soil extract and that of the insoluble residue

Fifty grams of soil was occasionally shaken for six days with 400 c. c. of water. The soil was filtered through filter paper in a Buchner funnel, and residue on the filter paper washed four times with 25 c. c. of water. The washings were mixed with the extract, which was removed. The residue was further washed with distilled water till free from soluble material as judged by the absence of chlorides. The catalytic power possessed by 50 c. c. of the above extract (equivalent to 5 gms. original soil) and 5 gms. of the residue was determined after thirteen days' exposure.

The results given in Table II show that :—

(1) The catalyst is both water soluble and insoluble.

(2) The residue is a better catalyst for mono-ethyl-amine than aniline. With the extract it is quite the reverse.

TABLE II

Showing the catalytic powers of soil extract and residue (mgm. nitrous nitrogen per 100 c. c. solution)

Serial No.	Extract		Residue	
	Aniline	Mono-ethyl-amine	Aniline	Mono-ethyl-amine
1	0·178	0·039	0·032	0·272
2	0·060	0·042	0·032	0·194
3	0·227	0·071	0·031	0·168
4	trace	0·024	0·029	0·168
5	0·022	0·019	0·027	0·181
6	0·648	0·104	0·041	0·337

III. CATALYTIC POWER OF THE IGNITED SOIL

All the six soils were ignited at 600°C. for three hours in the muffle furnace and their catalytic power determined, using five grams of the soil as before. Controls without mono-ethyl-amine or aniline were also exposed simultaneously. The contents of the flasks were analysed after five days' exposure. The soils showed only feeble catalytic action.

It seems that the loss of catalytic power is mainly due to the destruction of organic matter and soil colloids. These were tested separately.

1. Organic matter

Concentrated soil extract was prepared from *bara* and leaf-mold soils by shaking these with an equal amount of distilled water, and then filtering. The extract in five c. c. portions was treated with varying amounts of Merck's hydrogen peroxide (12 Vol. 'O') in well corked test tubes and kept overnight. The contents of the tubes were then transferred with distilled water in the conical flasks and the volume made up to fifty c. c. The catalytic power of the extracts was determined as usual.

The results given in Table III show that the catalytic action of *bara* soil extract is not affected by treatment with hydrogen peroxide, whereas in the case of leaf-mold soil, it decreased with increasing amount of hydrogen peroxide.

TABLE III

Leaf mold soil extract		*Bara* soil extract	
Treated with	Mgm. nitrous nitrogen per 100 c.c. solution	Treated with	Mgm. nitrous nitrogen per 100 c.c. solution
2·0 c.c. hydrogen peroxide.	0·551	1·0 c.c. hydrogen peroxide.	0·251
4·0 c.c. hydrogen peroxide.	0·324	2·0 c.c. hydrogen peroxide.	0·251
6·0 c.c. hydrogen peroxide.	0·259	3·0 c.c. hydrogen peroxide.	0·251
8·0 c.c. hydrogen peroxide.	0·162	4·0 c.c. hydrogen peroxide.	0·251
Control . . .	0·972	Control .	0·243

It would seem that the soluble organic matter from *bara* soil is either not attacked by hydrogen peroxide or it possesses a very slight catalytic power.

The soil extracts corresponding to five grams soil from both the soils were evaporated and the residue ignited at a low temperature and its catalytic power was determined after ten days' exposure.

The results given in Table IV provide additional proof of the fact that the soil organic matter acts as a catalyst.

TABLE IV

Showing the catalytic power of the soil extract and its ash

Serial No.	Catalyst	Mgm. nitrous nitrogen per 100 c.c. solution
1	Extract of soil No. 6	0.236
2	Ash of the above	0.045
3	Extract of soil No. 3	0.178
4	Ash of the above	0.032
5	Control	0.016

2. Soil colloids

(*a*) It is well known that collodion membranes generally possess the power of retaining colloids. The catalytic power of soil extracts filtered through collodion membrane and ordinary filter paper was determined as usual. It was found to be unaffected by filtration through collodion membrane. This shows that the colloidal matter in the extract, if any, has no catalytic power. The results are given in Table V.

TABLE V

Showing the catalytic action of soil extract when filtered through collodion membrane and ordinary filter paper

(Mgm. nitrous nitrogen per 100 c.c. solution)

Catalyst	Extract No. 1		Extract No. 2
	Aniline	Mono-ethyl-amine	Aniline
Extract through collodion filter	0·713	0·123	0·113
Extract through filter paper .	0·713	0·117	0·113

(*b*) Clay fractions (0·002 mm.) were separated from the soil residues as prepared under experiment II. In order to get rid of organic matter*, the clays were treated with Merck's hydrogen peroxide for twenty-four hours, when these were filtered and washed with distilled water ; extracted with ether in the Soxhlet extraction apparatus for about eight hours ; and then further extracted with redistilled alcohol for three hours ; filtered and again washed with alcohol a number of times and dried.

The clays so prepared were taken in two-gram portions and tested for catalytic action against mono-ethyl-amine. Nitrous nitrogen was determined after thirteen days' exposure. The results given in Table VI show that the clay acts as a catalyst.

* It is surely desirable to completely remove organic matter from the clay, but this is not possible without more drastic treatment, which may also change the clay complex, hence treatment with hydrogen peroxide followed by extraction with ether and alcohol was considered sufficient.

TABLE VI

Showing the catalytic action of clays from different soils

Catalyst	Mgm. nitrous nitrogen per 100 c.c. solution
Clay from soil No. 1	0·110
Clay from soil No. 4	0·052
Clay from soil No. 5	0·065
Control	0·013

Having thus found that the catalysts in soil are both organic and inorganic in their nature more elaborated study of these two groups was made.

IV. NATURE OF THE ORGANIC CATALYSTS IN SOIL

1. Soil fats and waxes

One hundred grams of leaf-mold soil was extracted with 200 c.c. ether in the Soxhlet extraction apparatus for twelve hours. Ether extract corresponding to ten grams soil was measured out in each flask and evaporated to dryness over water bath. The catalytic power of the ether residue was determined in the usual way. To avoid decomposition of the organic matter the flasks were not sterilized and instead dark controls were kept side by side with the exposed flasks.

The results given in Table VII show that ether-soluble organic matter, *i.e.* soil fats and waxes possess a fair amount of catalytic power.

TABLE VII

Showing the catalytic action of ether extract

Treatment	Mgm. nitrous nitrogen per 100 c.c. solution	
	Aniline	Mono-ethyl-amine
1 Ether extract (exposed)	trace	0.078
2 Ether extract (unexposed)	*nil*	*nil*
3 Control (without catalyst)	*nil*	0.029

2. Soil resins

The soil after treatment with ether was extracted with absolute alcohol over water-bath for about four hours. The extract was filtered and portions corresponding to ten grams soil were measured out in flasks. These were evaporated to dryness over water-bath, and the catalytic power of the residue was determined as in the case of ether extract.

The results given in Table VIII show that soil resins also have catalytic action.

TABLE VIII

Showing the catalytic action of alcoholic extract

Treatment	Mgm. nitrous nitrogen per 100 c.c. solution	
	Aniline	Mono-ethyl-amine
Alcoholic extract (exposed)	0·810	0·047
Alcoholic extract (unexposed)	*nil*	*nil*
Control (without catalyst)	*nil*	0·029

The mineral matter in the extract was also found to be slightly catalytic in action.

3. Humus.

Humus was extracted from soil in the usual way. It was purified by redissolving and precipitating. Finally the humus or to be more correct humic acid precipitated with hydrochloric acid was washed with distilled water a number of times to get rid of ammonium chloride and hydrochloric acid. It was shaken with distilled water in a stoppered cylinder and a portion corresponding to five grams soil was tested as a catalyst. The catalytic power was determined in the usual manner. The analysis was done after twelve days' exposure.

The results given in Table IX show that both humus and its ash act as catalysts.

TABLE IX

Showing the catalytic action of humus

Serial No.	Treatment	Mgm. nitrous nitrogen per 100 c.c. solution
1	Humus with mono-ethyl-amine (exposed) . .	0·130
2	Humus with mono-ethyl-amine (unexposed) .	*nil*
3	Humus ash with mono-ethyl-amine (exposed) .	0·071
4	Humus without mono-ethyl-amine (exposed) . . .	*nil*
5	Control	0·026

4. Cellulose

The catalytic power of Whatman filter paper cellulose was determined using one gram filter paper as a catalyst.

The results given in Table X show that impure cellulose acts as a catalyst.

TABLE X

Showing the catalytic action of filter paper

Catalyst	Mgm. nitrous nitrogen per 100 c.c. solution	
	Aniline	Mono-ethyl-amine
Filter paper	Trace	0·042
Control	*Nil*	0·016

The experiment was repeated with purified cellulose from cotton wool. The results were negative.

The catalytic power of impure cellulose was found to have increased after bacterial decomposition.

Fifty c. c. culture medium of the composition given below* was transferred to each of the four 300-c. c. conical flasks. One gram filter paper strips were added to each.

These were inoculated with a drop of fresh horse dung extract. Two of these were sterilized, and kept along with the other two in the incubator at 30°C. for a month. When the cellulose in the unsterilized flasks was macerated, the catalytic power of the contents of the flasks against mono-ethyl-amine was determined after six days' exposure. The catalytic action of the decomposed filter paper was found to have increased. The results are given in Table XI.

Potassium hydrogen phosphate	1·0 gram.
Magnesium sulphate	1·0 „
Sodium chloride	1·0 „
Ammonium sulphate	2·0 „
Distilled water	1000 c.c.

TABLE XI

Showing the catalytic action of filter paper and its decomposition products

Serial No.	Catalyst	Mgm. nitrous nitrogen per 100 c.c. solution
1	Decomposed filter paper	0·062
2	Filter paper	0·036
3	Control	0·014

Cellulose present in soil is very likely to behave as filter paper above. The increased action may be due either to the decomposition products of cellulose or to the bacterial bodies. This point is still to be investigated. There is a certain amount of evidence to show that bacterial bodies also act as photo-catalysts. The work is in progress.

Since soil organic matter is mostly derived from plant waste materials, extract from green plants was also tried as a catalyst. A few green stalks of berseem (*Trifolium alexandrinum*) well washed with distilled water were extracted with absolute alcohol. Five c. c. of the extract was evaporated to dryness over water-bath in a flask and the catalytic power of the residue was determined without sterilizing but with dark controls. The contents of the flasks were analysed after four days'

exposure. The alcoholic extract of the green stalks exhibited catalytic property. Extract of non-legumes also showed a similar action. Results are given in Table XII.

TABLE XII

Showing the catalytic action of alcoholic extract of green berseem leaves

Treatment	Mgm. nitrous nitrogen per 100 c.c. solution	
	One per cent mono-ethyl-amine	*N*/10 ammonia
Alcoholic extract (exposed)	0·097	0·014
Alcoholic extract (unexposed)	*nil*	*nil*
Control (exposed)	0·012	Trace

Aquous extracts of the plants were also found to be catalytic in action.

This shows that plant leaves have the power of oxidising ammonia in sun light. Free ammonia is said to be toxic to plant life, but the plant may be able to utilize it because of its catalytic power. Work on plant catalysts is in progress.

5. Inorganic catalysts in soil

Since soil is mainly a mineral complex, the method of study adopted in this case was to try different metallic bases as catalysts.

In most cases the oxides of the metals were used. The catalytic power possessed by one gram of the bases was determined as before using aniline and mono-ethyl-amine as the ' substrate '. Exposed and unexposed flasks were kept both, with and without the ' substrate '.

Since the oxides are generally prepared by the ignition of nitrates there is possibility of their contamination with nitrates, nitrites or other nitrifiable compounds. So in order to avoid errors due to these sources, controls (both exposed and unexposed) without the ' substrate ' were also prepared.

The contents of the flasks were analysed after a fortnight. Oxides of lithium, manganese, bismuth, lead, nickel, copper, mercury, and chlorides of potassium calcium, barium, magnesium, showed catalytic action. Stannic chloride, antimony, tetroxide and ferric oxide gave negative results. The action of the remaining compounds, with the exception of bismuth trioxide and mercuric oxide was very feeble

This would indicate that the catalytic action of the soil is mainly a function of the organic matter it contains.

It has been found that the nature of the acid radical in combination with the base considerably modifies the catalytic power of the metallic ion ; the catalytic properties of some of the more important clays were also investigated.

A clay soil was taken, and it was exhaustively washed with $N/20$ hydrochloric acid till the filtrate gave no test for calcium. It was now washed free of acid with distilled water. The clay (0·002 mm.) was separated by centrifuging. It was dried over water-bath, treated with Merck's hydrogen peroxide over night, again dried, extracted with ether and then with alcohol. Different clays were prepared from this by washing the hydrogen clay over Buchner funnel with small quantities of normal solutions of the metallic clorides. The washings were continued till the filtrate gave no acid reaction. The clay was then washed with distilled water till free from chlorides.

Two grams of the clay as prepared above was used as a catalyst for the oxidation of mono-ethyl-amine. Dark controls were also kept. Nitrous nitrogen was determined after sixteen days' exposure. The results given in Table XIII show that the different clays are catalytic in action and sodium and potassium clays are more vigorous in this respect than the others.

TABLE XIII

Showing the catalytic action of different clays

Serial No.	Catalyst	Mgm. nitrous nitrogen per 100 c.c. solution
1	Control	0·029
2	Calcium clay	0·039
3	Hydrogen clay	0·060
4	Magnesium clay	0·065
5	Manganese clay	0·036
6	Potassium clay	0·110
7	Sodium clay	0·110

Conclusions

1. Catalytic power varies with different soils.

2. The oxidising power of a catalyst differs with different compounds.

3. Soil fats, waxes, resins and humus act as catalysts.

4. Impure cellulose possesses catalytic power, which increases on its bacterial decomposition.

5. Alcoholic extract as well as aquous extract of plants also show catalytic action.

6. Water soluble mineral matter in the soil, clay, chlorides of potassium, barium, calcium, magnesium, and oxides of manganese, lithium, bismuth, lead, nickel, copper and mercury all possess some catalytic power which is quite well pronounced in the case of bismuth and mercury.

7. Sodium and potassium clays are better catalysts than calcium, hydrogen, magnesium and manganese clays.

8. The bacterial nitrification in mono-ethyl-amine and aniline solutions was negligible as compared to the photo-nitrification in the presence of soil.

REFERENCES

Dhar, N. R. ; Bhatacharya, A. K. and Biswas, N. N. (1933). *Soil Sci.* **35**, 281.
Sarkaria, Ram Singh and Fazal-ud-din (1933). *Ind. J. Agric. Sci.* **3**, 1057.
Rao, G. G. and Dhar, N. R. (1931). *Soil Sci.* **31**, 379.

PHOTO-OXIDATION OF SULPHUR

BY

FAZAL-UD-DIN, B.Sc.,

Bacteriological Assistant, Agricultural Research Institute, Lyallpur

(Received for publication on 14th January, 1935)

Introduction

Bacterial oxidation of elemental sulphur and its chemical oxidation at a high temperature are well known. Kappen and Quensell [1915] were the first to show that chemical oxidation of sulphur at room temperature is possible under the influence of soil catalysts and that considerably large quantities of sulphur are oxidised in unsterile than in sterile soils. These findings were later confirmed by MacIntire, Gray and Shaw [1921].

While photo-oxidation of certain nitrogenous compounds was being studied in this laboratory, it seemed interesting to see if elemental sulphur could also be oxidised photo-chemically.

Experimental

One gram of Kahlbaum's precipitated sulphur and fifty c. c. of water were taken in each of thirty-two Pyrex glass flasks of 300 c. c. capacity. These were divided into four sets and each set was submitted to the treatment as shown below :—

1. No treatment.
2. One gram zinc oxide per flask.
3. One gram animal chracoal per flask.
4. Five grams field soil per flask.

A fifth set of eight flasks each containing fifty c. c. of distilled water and five grams of soil was also prepared to see if there was any change in the sulphate content of the soil on exposure to the sun.

The flasks were plugged with cotton wool and sterilized in flowing steam for thirty minutes on three consecutive days and the plugs covered with paper to protect them from dust. Four flasks in each set were wrapped with black paper and these along with the rest were kept in the sun.*

The contents of the flasks were analysed for sulphates by the usual gravimetric-method after sixty days and the results are given in Table I.

* The experiments described in this paper were all carried out during summer months.

TABLE I

Showing photo-oxidation of sulphur

Set No.	Description	Grm. barium sulphate per flask		Mean difference
		Exposed	Unexposed	
1	Sulphur without catalyst .	0·0044	Trace	0·0050
		0·0042	,,	
		0·0062	,,	
		0·0054	,,	
2	Sulphur + zinc oxide . . .	0·0124	Trace	0·0097
		0·0098	,,	
		0·0090	,,	
		0·0078	,,	
3	Sulphur + animal charcoal . . .	0·0964	0·0500	0·0443
		0·0926	0·0430	
		0·0900	0·0478	
		0·0888	0·0496	
4	Sulphur + soil . . .	0·0700	0·0164	0·0534
	. . . .	0·0726	0·0172	
		0·0684	0·0162	
		0·0670	0·0148	
5	Soil without sulphur . . .	0·0078	0·0078	0·0001
		0·0072	0·0070	
		0·0072	0·0074	
		0·0076	0·0072	

The original sulphates in one gram of animal charcoal and five grams of soil were also estimated and found to be 0·0100 grm. and 0·0074 grm. respectively when weighed as barium sulphate.

It is evident from the above figures that sulphur is oxidised photo-chemically. Zinc oxide showed only a feeble catalytic action. The action of animal charcoal and soil, however, was more pronounced.

In the cases of animal charcoal and soil the oxidation of sulphur proceeded also in the dark.

Another experiment was conducted to see if the oxidation of sulphur could be stimulated by an alkaline solution.

One gram of sulphur, two grams of animal charcoal and fifty c.c. of water were added to eight different flasks. Of these four flasks received 5·0 c.c. *N*/10 sodium hydroxide each and the flasks after sterilization were exposed to the sun. The contents of the flasks were analysed after five months. The results given in Table II show a slightly greater degree of oxidation in the flasks containing soda.

TABLE II

Showing the oxidation of sulphur in the presence and absence of sodium hydroxide

Serial No.	Gm. barium sulphate per flask		Difference
	With sodium hydroxide	Without sodium hydroxide	
1	0·1770	0·1722	0·0048
2	0·1698	0·1582	0·0116
3	0·1776	0·1600	0·0176
4	0·1734	0·1558	0·0176
Mean	0·1744	0·1615	0·0129

A statistical examination of the differences given in the last column of the above table was made. These values were found to be subject to a standard deviation of $\pm 0{\cdot}0061$. The standard error of the mean difference was therefore estimated to be $\frac{0{\cdot}0061}{\sqrt{4}}$ or 0·003. The significance of the mean difference 0·0129 was tested against its standard error by Fisher's '*t*'-test. The value of '*t*' was determined to be 4.2. The expected value of '*t*' from Fisher's '*t*'-table for level of significance 0·05, was found to be 3·18, which is less than the value obtained from the differences examined. The effect of caustic soda on the oxidation of sulphur was thus found to be quite significant.

The oxidation of sulphur in soil may either be bacterial, chemical or photochemical. In order to compare the bacterial oxidation of sulphur in soil with the other two processes, 200 grms. of soil were taken in three separate conical flasks of 500 c. c. capacity and two per cent of sulphur was added in two of them. A moisture* content of 13 per cent was supplied to all three. In one of the flasks containing sulphur moisture was supplied by the aid of a mercuric chloride solution saturated

*Thirteen per cent moisture was the optimum for the activity of aerobic bacteria in the soil.

at 25°C. and in the others with distilled water. The flasks were exposed to the sun, and the loss of moisture was made up from time to time, and the contents of the flasks analysed after sixty days. The absence of sulphur-oxidising bacteria in soil treated with mercuric chloride was tested before analysis. About a gram of the soil was inoculated in each of the six conical flasks containing fifty c.c. of sterile medium of the following composition :—

Ammonium sulphate	0·2 grm.
Magnesium sulphate	0·5 „
Mono-potassium phosphate	1·0 „
Calcium phosphate reprecipitated	2·5 grms.
Sulphur	10·0 „
Distilled water	1000 c.c.

$\frac{M}{1}$ phosphoric acid suffientie to adjust the reaction to pH 4·0.

Three of the flasks were again sterilized and these along with the rest were kept in the incubator at 30°C. The reaction (pH) of the contents in each flask was determined after six weeks and was found to be the same in all cases, showing that the soil was free from sulphur-oxidising bacteria.

The results given in Table III show that chemical oxidation of sulphur in soil is very slight compared with biological oxidation.

TABLE III

Showing the oxidation of sulphur in soil

Treatment	Grm. barium sulphate from 5 grams of soil
Soil alone	0·0058
Soil + sulphur	0·2222
Soil + sulphur + mercuric chloride	0·0092

CONCLUSIONS

1. Elemental sulphur is oxidised photo-chemically.

2. Zinc oxide, animal charcoal and soil act as photo catalysts.

3. Chemical oxidation of sulphur in soil is negligible compared with the biological effect.

REFERENCES

Kappen, H., and Quensell, E. (1915). Uber die Umwandlungen von Schwefel und Schwefelverbindungen im Ackerboden, ein Beitrag zur Kenntnis des Schwefel-Kreislaufes : *Landw. Vers. Stat.* **86**, 1—34.

MacIntire, W. H. ; Gray, F. J. ; and Shaw, W. M. (1921). *Soil Sci.* **11**, 249.

SUGARCANE IN THE PUNJAB, PART I

BY

P. E. LANDER, M.A., D.Sc., F.I.C.,

Agricultural Chemist to Government, Punjab

AND

RAMJI NARAIN, PH.D., D.Sc.,

Assistant to the Agricultural Chemist, Punjab, Lyallpur

(Received for publication on 2nd October 1934)

(With Plates XIV and XV and sixteen text-figures)

CONTENTS

	PAGE
PREFACE	214
INTRODUCTION	215
1. The South-Eastern tract	216
2. The Central tract	220
3. The Sub-Montane tract	223
THE EFFECT OF FROST ON SUGARCANE	226
DISEASES AND PESTS	233
FLOWERING OF SUGARCANE	235
RATOONING	236
FIBRE	237
EFFECT ON THE CANE CROP OF WITHHOLDING WATER FROM OCTOBER ONWARDS	238
EFFECTS OF ARTIFICIAL MANURES ON SUGARCANE	239
SUMMARY	240
TABLES I—LXV	244
FIGURES 1 TO 16	330

PREFACE

The authors wish to record their appreciation and acknowledgment of the valuable assistance given by the Deputy Directors of Agriculture and their assistants of the Hansi, Jullundur and Gurdaspur Circles, in carrying out these surveys. They also wish to record the ready co-operation afforded by zamindars in all the areas mentioned, in reserving plots of cane for analysis and other valuable help.

The surveys described in this paper were carried out by Mr. K. K. Paracer, S. Balwant Singh Mahon, and L. Jiwan Dass, of the Chemical Section in the Karnal-Rohtak, Jullundur-Hoshiarpur and Gurdaspur-Sialkot districts, respectively. Our acknowledgments are due to them for the painstaking care and zeal with which they carried on this work. Special credit is due to S. Balwant Singh for his assistance in the enormous amount of work entailed in the computation and arrangement of the data which represent the results from over four thousands analyses.

Lyallpur,
15th August 1934

P. E. Lander
Ramji Narain

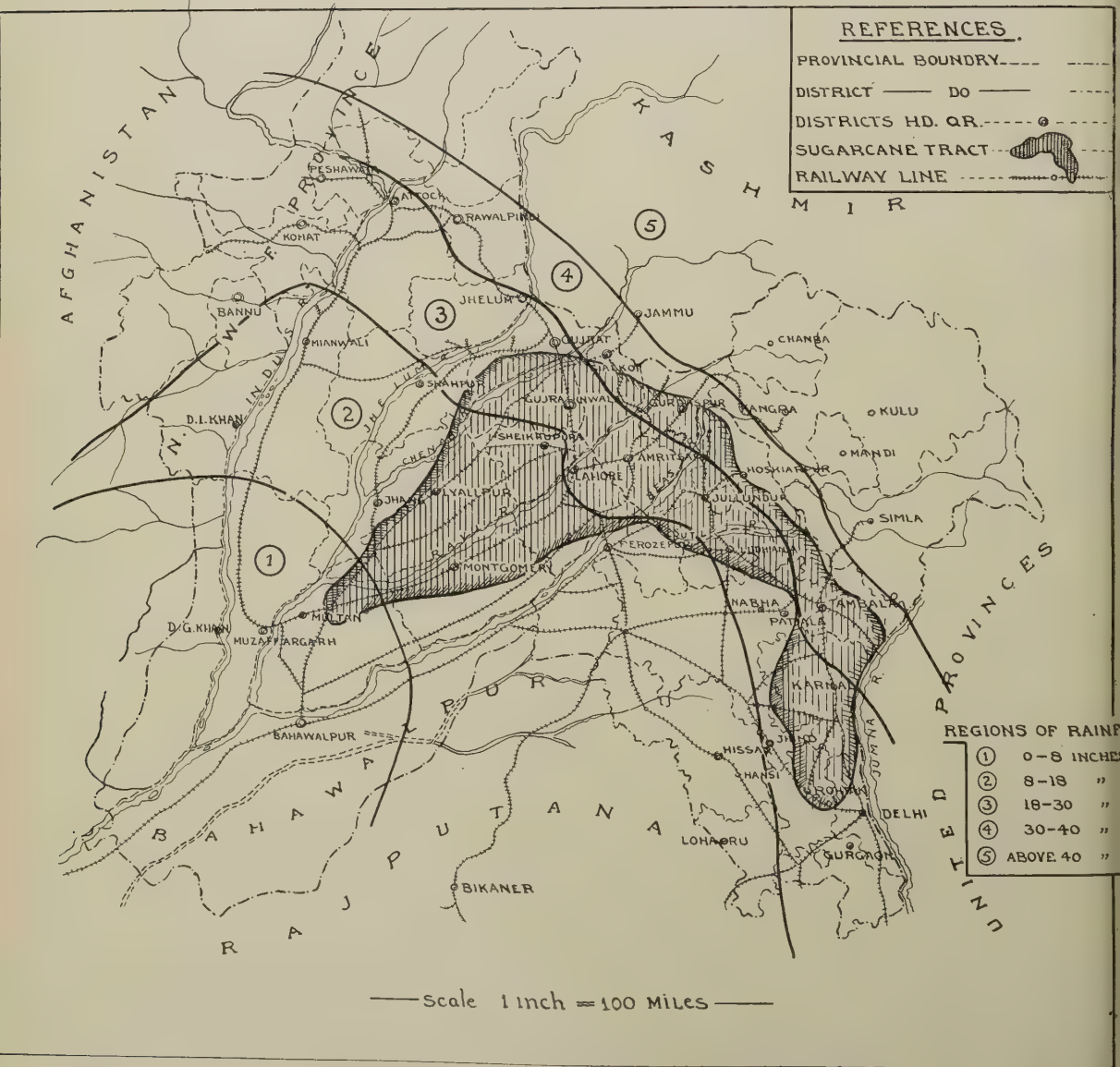
MAP OF THE PUNJAB

SHOWING.

MAIN SUGARCANE TRACT INCLUDING DISTRICTS WITH AN ACREAGE OF 10,000 OR ABOVE

&

DISTRIBUTION OF AVERAGE RAINFALL



INTRODUCTION

The activities of the Punjab Department of Agriculture in investigating and developing the production of cane in this Province date back to 1911, when Gurdaspur, the district with the then largest area under cane, was selected for starting work on varietal tests.

These tests were carried out at the Gurdaspur Agricultural Experimental Station over a period of seven years, and the results published as a Bulletin of Agricultural Research Institute, Pusa [Barnes, 1918].

Similar work was also carried out during this period at Lyallpur.

The necessity for more extended systematic work both on cane growing in the field, and factory requirements was recognised, and in 1919 the Government of India appointed the Indian Sugar Committee under the Chairmanship of Mr. J. Mackenna, Agricultural Advisor to the Government of India, whose terms of reference were to investigate the possibilities of organising and developing the sugar industry of India.

This Committee published its report in 1921 and made certain specific recommendations in regard to the Punjab, to the effect that work should be extended on trials of improved varieties imported from other Provinces, exotics, and also improved crosses from Coimbatore.

These recommendations were given effect to, and as a result of subsequent investigations on most of the main Government Farms, a number of approved new varieties was adopted by the cultivators of the Punjab.

In August 1926 Mr. Noel Deerr of Messrs. Begg, Sutherland & Co. was invited by the Director of Agriculture, to tour the principal cane growing areas of the Punjab with the object of studying the cane situation then existing, and to advise on the possibility of establishing efficient modern factories to supersede the acknowledged inefficient methods in vogue.

Mr. Noel Deerr recognised that some of the new varieties such as Co. 205, Co. 223, etc., had been definitely adopted in various parts of the Province and that theygave yields far in excess of those hitherto obtained by the old indigenous varieties such as *Katha, Kahu, Dhaulu,* etc. In his report submitted in November 1926, he also laid stress on the fact that for the successful working of a sugar factory it was essential that the crushing season be extended to the middle of April and that the high yielding new Coimbatore canes should supplant the *desi* varieties.

This report was considered by the Sugar Sub-Committee of the Joint Development Board, as a result of whose deliberations, it was suggested that the Agricultural Chemist to Government, Punjab, should carry out a systematic analytical survey

of the canes grown in the Karnal, Gurdaspur, and Jullundur districts, as it was considered that these were the districts which might prove most suitable for establishing factories.

An important aspect of this enquiry was to ascertain the effect of frost and other factors on the various varieties grown in these areas, with the particular object of finding out those canes which could keep a factory supplied with ripe raw material throughout an economic working season.

A systematic enquiry based on these lines was accordingly carried out in the districts mentioned over a series of years from 1927 to 1932, the results of which are presented in the following pages.

The following localities were surveyed :—

1. Karnal and Rohtak districts, representing the south-eastern sugarcane growing tract of the Province (the survey in this area came to an end in 1930-31).
2. Jullundur and Hoshiarpur districts, representing the Central Punjab and,
3. Gurdaspur and Sialkot districts representing the sub-montane tracts.

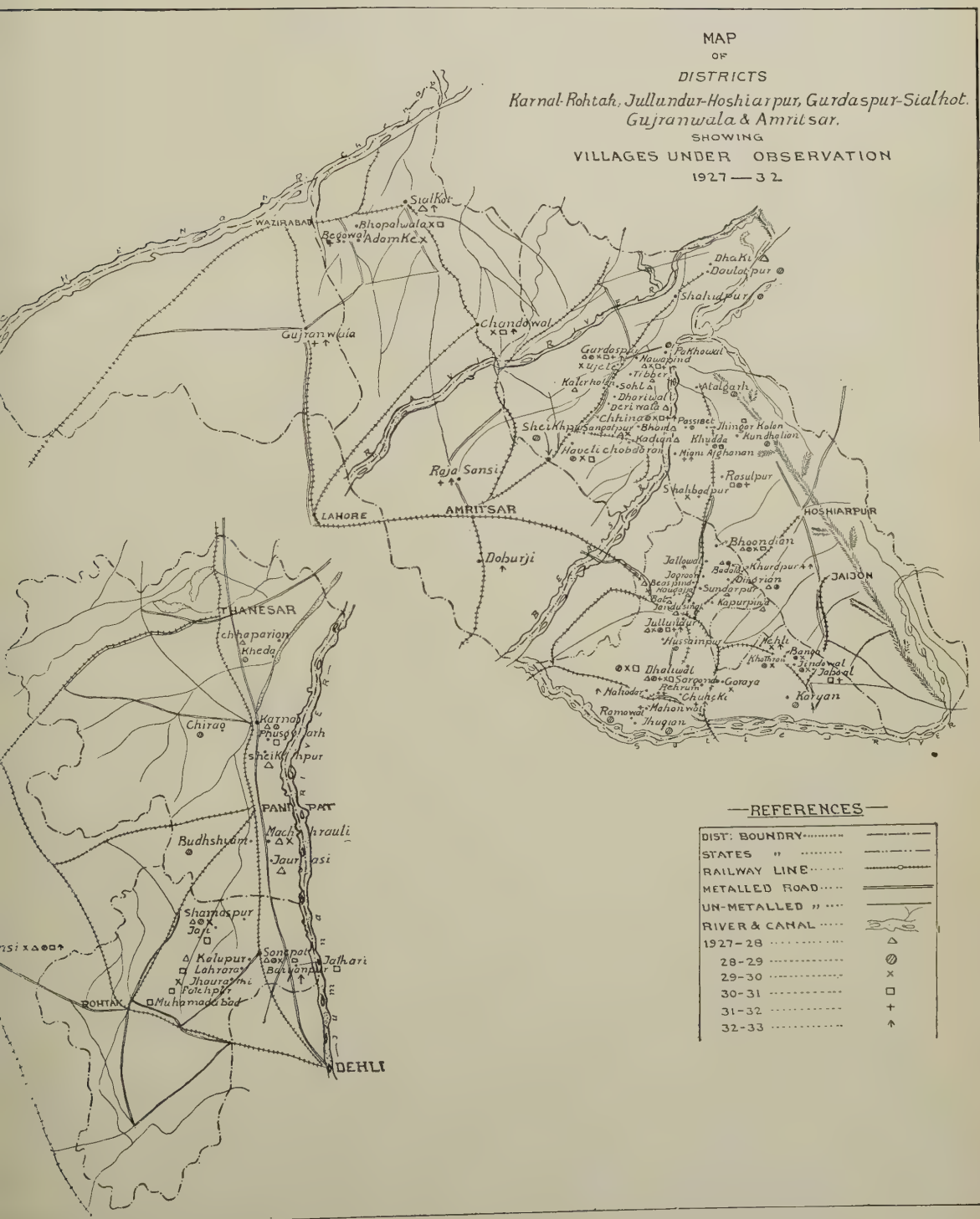
A chemical assistant was posted to each and arrangements made for representative types of selected canes to be analysed at fortnightly intervals throughout the cane season from November to the middle of April, both from the Government Farms and from the land of zamindars at various spots throughout the districts.

1. The South-Eastern Tract (Karnal and Rohtak districts)

(*a*) *General physical and climatic conditions.*—Karnal and Rohtak which contain the largest areas under sugarcane of the south-eastern cane growing districts of the Punjab belong to the Western Gangetic Plain, with a mean annual rainfall of about 24 inches. The soils of this area consist mostly of medium loams, which are sufficiently retentive of moisture, and, given adequate irrigation, are extremely fertile.

The consumption of sugar in this area is high and there is a big local demand both for raw and refined sugar.

Frost is not as common an occurrence as in some other parts of the Province, and thus this tract offers very suitable conditions for cane growing. The high temperatures, combined with the high humidity, which are experienced are very favourable for the growth of cane during the monsoon period, but unfortunately, these conditions are limited in duration, and are offset to some extent by the earlier hot dry months, and the succeeding cold season.


MAP
OF
DISTRICTS
Karnal-Rohtak, Jullundur-Hoshiarpur, Gurdaspur-Sialkot.
Gujranwala & Amritsar.
SHOWING
VILLAGES UNDER OBSERVATION
1927—32.
SialKot
WAZIRABAD
Bhopalwala
Begowal
Adam Ke
Gujranwala
Chandowal
Dhaki
Doulat pur
Shalidpur
Gurdaspur
Pathowal
Nawabad
Ujela
Tibber
Kalerkalan
Sohl
Atalgarh
Dhariwal
Deriwala
Chhina
Passiee
Jhinger Kalan
Sheikhupur
Sangatpur
Bhoma
Kadian
Khudda
Kundhalian
Haveli chobaran
Migni Afghanan
Raja Sansi
Rasulpur
Shahbadpur
LAHORE
AMRITSAR
HOSHIARPUR
Doburji
Bhoondian
Jallowal
Budala
Khurdpur
Jagroan
Dhadrian
Beas junction
Nawasar
Sundarpur
Kapurpind
Bate
Jandu Singha
JAIJON
Jullundur
Hussainpur
Nehli
Banna
Khatkar
Jindowal
Jabowal
Dhaliwal
Sarona
Goraya
Fatehpur
Mahoda
Chuhe Ki
Karyan
Ramowal
Mahonwali
Jhugian
THANESAR
Chhaparian
Kheda
Chirao
Karnal
Nausgarh
Sheikhpur
PANIPAT
Budhshyam
Machhrauli
Jaurasi
Shamaspur
Jaf
Kalupur
Lahrara
Jhauratmi
Patchpir
Muhamadabad
Sonepat
Bahlumpur
Jalhari
ROHTAK
DEHLI
REFERENCES
DIST: BOUNDRY
STATES "
RAILWAY LINE
METALLED ROAD
UN-METALLED "
RIVER & CANAL
1927-28
28-29
29-30
30-31
31-32
32-33

These climatic factors with extremes of temperature necessarily impose certain limitations on the yield and quality of cane produced.

(*b*) *Agricultural features.*—As the cane growing tracts of Rohtak and Karnal are only separated by the River Jumna from the corresponding districts of Meerut and Muzaffarnagar of the United Provinces, they show similar climatic factors and the general agricultural methods employed are essentially the same.

The soils are alluvial, varying from some stiff clays in the Karnal district to clay and medium loams in a more southerly direction. Hence with a well distributed rainfall of 25 inches per annum, supplemented by canal or well irrigation they are eminently suitable for cane.

The rotations usually followed are :—

1. Wheat—>Maize—>*Metha* and Sugarcane.
2. Sugarcane—>Wheat—>*Jowar*, *Bajra* or *Gowara*, and Gram.
3. Sugarcane—>Wheat—>Chillies or Cotton.
4. Sugarcane—>Wheat—>*Jowar*, *Bajra*, or Cotton and *Metha*.
5. Sugarcane—>Wheat—>Cotton, Wheat or Wheat+Gram (mixture).

Sugarcane and wheat are invariably manured, farmyard manure being used and applied to every crop when available. In a normal year cane receives from 400 to 600 mds. of manure per acre, from 10 to 15 irrigations, and is intercultured from 6 to 10 times with hand implements.

(*c*) *Varieties of cane grown.*—Most of the local varieties ripen early. Lalri, a thin cane, resembling Katha, more common to the Central districts, is extensively grown on well and canal irrigated land in the Karnal, Rohtak and Gurgaon districts. It has a good tillering capacity, is a hard frost resistant cane and is capable of surviving conditions which would be fatal to medium or thick varieties. The yield in juice is lower and the cane more fibrous than Suretha, but the juice has a high sucrose content.

The outturn is from 15 to 18 tons of cane per acre, giving about 1·5 tons of *gur*.

Suretha is a thicker, softer and whiter cane than Lalri, requires more irrigations and is liable to suffer from drought, but under suitable conditions it attains a considerable height and yields about 20 tons or even more per acre.

Dhaulu, which is a white, soft, chewing cane, is usually grown with Bodichin under *barani* conditions. Its average yield per acre is 25 tons of stripped cane yielding from 2 to 2·5 tons of *gur*, which fetches a high price in the market.

Manure is not usually applied to Dhaulu, which follows the rotation Cane—Fallow—Cane. This variety, however, is particularly susceptible to frost and pests, and suffered very severely in the 1928-29 season on this account.

Of the Coimbatore varieties, Co. 205, Co. 213, and Co. 223, were usually grown on an area which was increasing year by year.

Co. 205 gives a comparatively low sucrose content and high glucose ratio, possesses a long deep root system and will tolerate the disadvantages of *barani* tracts, poor and indifferent cultivators, and is immune to most of the prevalent diseases of cane.

Its yield in this locality has been about 2·5 tons of *gur* per acre, although far greater yields have been obtained at the Lyallpur Agricultural Station.

Co. 213 and Co. 223 resemble each other as regards their sucrose and glucose. content and high yields which amount to about 3 tons of *gur* per acre, provided sufficient manure and watering is given, but otherwise the yield is much lower, Co. 223 is, however, a soft cane and consequently liable to damage by jackals and other animals, and on this account it has lost favour with the cultivators to such a degree that during the 1930-31 season, it was not grown on any appreciable scale, while the area under other improved varieties steadily increased.

Other varieties, such as Co. 300, and Co. 312, have also been introduced in these localities. The Coimbatore varieties, in addition to their high yields possess considerable power of ratooning, and this is an additional reason for their increasing popularity.

(*d*) *Period of optimum ripeness.*—Harvesting generally begins by the middle of November, and is continued till the end of February, although, occasionally, when winter rains delay ripening, it extends well into March.

The above-mentioned varieties provide for a crushing season of about 4 months which is requisite for the successful working of a factory, although the average zamindar prefers to clear his fields at the earliest date possible. The period of optimum ripeness, the requirements of the zamindar and the needs of the factory require, therefore, careful adjustment if the best all-round advantage is to be obtained.

The introduction of high yielding new varieties is no doubt helping the zamindar to extend the period during which his cane can be left standing, but in order to conform to general agricultural practice in these localities, an extension of the crushing season must be combined with the introduction of early ripening varieties, which owing to high yields and frost resisting qualities will be able to replace the local Lalri.

Analyses of different varieties of cane during the years of the survey show that canes in a mature condition fit for crushing are available by the first week of December and may continue so until the first week of April (Table VIII).

Co. 300, Co. 301, and Co. 313 are early ripeners and have done very well in Jullundur and Gurdaspur, and there appears to be no reason why they should not do equally well or better in the more equitable climate of the south-eastern Punjab to which they have recently been introduced, although analytical data have not yet been obtained.

Shah-Nahr which irrigates parts of the Bet lands. No definite or fixed rotations are followed in this tract. In the Bet area ratooning is very commonly practised and it has been found that the second and third crops give better yields than the first. This practice is sometimes extended to the 6th or 7th year although the yield generally begins to fall off after the fourth year.

(*c*) *Varieties commonly grown.*—During the first year of this survey, 1927-28, the most common indigenous varieties grown were Ponda, Katha, Dhaulu, and Yuba, together with Kinara and Ekar to some extent, Katha everywhere predominated, however, and was the only cane grown under '*barani*' condition.

Ponda was grown chiefly near towns, but had never been used for sugar making ; Dhaulu was confined to '*chahi*' lands, while Yuba, owing to its great susceptibility to frost had almost disappeared.

The most important new varieties introduced have been Co. 205 and Co. 223, with Co. 213, as the latest arrival.

During the second and third year of the survey, 1928-30, although Katha was the only local variety found in any quantity in these two districts, some cultivators adopted the new Co. varieties to the entire exclusion of local ones, and inspite of some prejudice against it Co. 205 retained its position as it adapted itself better to ratooning and was not liable to attack of white ants, jackals, etc.

Co. 223, owing to its high yields, and producing a better quality *gur*, was very enthusiastically taken up to begin with. It showed, however, the disadvantages of having a characteristic hollow in the pith, and a split in the skin which rendered it liable to attack by pests and was gradually discarded, so much so, that by the time the survey was concluded it had almost gone out of cultivation except on poor lands. On the other hand Co. 213, owing to its good yield, high sucrose content, great vigour and excellent behaviour at maturity was enjoying an increased popularity.

In the 1931-32 season three more varieties Co. 281, Co. 285, and Co. 290 were investigated in more favourable parts of the district. Co. 285, in addition to being as high yielding as Co. 205, showed equal vigour and was also an early ripener with a low glucose ratio, and has in consequence largely replaced both Katha and Co. 205.

(*d*) *Period of optimum ripeness.*—Ratoon and '*barani*' crops which ripen early are generally the first to be harvested, thus Katha is ready by the middle of November and sometimes earlier and crushing is finished before the advent of frost.

The Coimbatore varieties, on the other hand for the most part, ripen late.

In tract 'B' including the Bet area of the Hoshiarpur district (Tract 'A' includes the Dhak and Manjki areas and tract 'B' includes the Sirwal and Bet lands around Tanda and the Government Agricultural Farm at Jullundur) frost is usually very severe, and unless frost resisting varieties are introduced for the later part of the season, a prolonged crushing season is not possible for factory requirements.

Part of the Jullundur Tehsil, and the whole of the area included in tract ' A ' are well adapted for a long crushing season, with Katha and a correct selection of Co varieties.

The periods of optimum ripeness of the varieties of cane analysed during the entire period of the survey are shown in Table XVII.

It appears from this that in normal years crushing could start before the end of November and be continued to the middle of March, the actual period in any year being liable to vary according to the climatic conditions prevailing.

A prolonged dry season at the beginning of winter would tend to ripen the cane earlier and conversely a long spell of wet weather would retard ripening.

Thus in 1932-33 the season was absolutely dry from the first week of September to the third week of December, and a dry cold January and February succeeded with 28 frosty nights, the result of which was a crushing season which extended from November to the end of April, *viz.*, 175 days compared with 130 days in the previous year.

Manuring also has a decided effect on the ripening period, generally delaying it, and it is a common observation that most practices which in any way help to increase yields such as excessive water supply, manuring, etc., tend to delay ripening.

Thus in irrigated areas these two factors give the farmer a certain degree of latitude in controlling the ripening period of his crops.

(*e*) *Quality of the canes.*—The data presented in Tables IX to XVI show the yields per acre and the composition of the juice from the different varieties of cane analysed. As in the case of the Gurdaspur canes, it will be seen that the composition of any variety varies only within very narrow limits from year to year, unless of course, a cane be badly attacked by disease or pests, as was the case with Co. 213, Co. 281, and Co. 285 at the Jullundur Agricultural Farm during the 1930-31 season and with Co. 223 at Khothran when the sucrose percentage fell as low as 5·7 (*see* page 233).

Very considerable differences in tonnage yield are, however, experienced with the same cane from year to year, or at different localities in the same year. For example the average yield of Co. 223 was 15·4 tons in 1928-29 as against 26·83 in 1931-32, the reason apparently being that the former season was a uniformly bad one for the cane crop while the 1931-32 season was a very good one.

Again in 1928-29 the yield from this variety varied from 8·6 tons at Jindowal to 23 tons at Nawapind, while Katha varied from a yield of 8·9 tons at Sargondi to 20·3 at Bhoondian, due to what may be termed ' local causes '.

Taking into consideration these differences in yield the average figures given in Table XV show representative ' normal ' yields, such as may be expected for the locality, unaffected by adverse or very favourable conditions.

(*e*) *Quality of the cane.*—Quality is an important consideration in factory requirements. Not only is it necessary to have a cane with a low fibre content, but as thick a juice as possible is desirable from the point of view of fuel consumption. A high purity coefficient and a low glucose ratio are also necessary, otherwise the sucrose fails to crystallize out properly as white sugar.

These factors are revealed in Tables I—VII of the analytical data collected during the years of the survey. The canes were analysed at fortnightly intervals from November to the middle of March and the figures shown are the averages of those obtained during the periods of optimum ripeness.

(*f*) *Comparison of indigenous and Coimbatore varieties.*—From the data collected it is easy to interpret the value of the two types of cane, which is summarised in terms of comparative average figures below :—

Outturn in tons per acre

	Stripped cane	Juice	Total solids	Sucrose	Glucose ratio	Purity coefficient
Local . .	24·60	12·70	2·42	2·01	1·50	84·38
Coimbatore .	26·67	15·13	2·93	2·42	2·16	86·05

It is clear that the Coimbatore varieties are in every way superior to the local varieties.

The glucose ratio is certainly higher, due to the inclusion of Co. 205, which has an exceptionally high glucose ratio and, but for its high yielding capacity and ability to withstand unfavourable climatic variations, would never have become popular either for *gur* or sugar production. It is, however, being gradually replaced by better types.

(*g*) *Effect of frost.*—As already stated these districts do not usually experience severe frost, and it is an uncommon experience to find cane damaged on that account to any appreciable extent, although when the whole Province experienced a fairly long spell of severe frost in the 1928-29 season, its effects were felt on the cane crop in these districts, and these will be discussed later in connection with the canes from the central and sub-montane areas.

2. *The Central Tract* (*Jullundur and Hoshiarpur districts*)

(*a*) *General physical and climatic conditions.*—These two districts lie between 30° 57′ N. and 32° 58′ N., being bounded on either side by the Sutlej and Beas, and form what is commonly known as the Doaba.

This area contains about 17 per cent of the total area under cane in the Punjab and has for long been regarded as the focus of the sugar industry whose decline in past years was largely due to foreign competition in Indian markets.

In the Hoshiarpur district the northern half of which is a mountainous tract containing the Siwaliks, a series of low-lying rocks forming the Sub-Himalayas and consisting of tertiary sandstone, clay and boulder conglomerates, runs along its entire length, the long strip of land from 3 to 8 miles in width bordering on Jullundur known as the Sirwal, is the most fertile part of the district in which most of the cane is grown.

The land lying between the Sirwal and the river Beas, known as the Bet, is unirrigated, and in it cane is produced under '*barani*' or '*sailab*' conditions, rendered possible by an average rainfall of 30-35 in. and a soil which does not dry rapidly.

The Jullundur district, however, further away from the foothills of the Himalayas, is better and has an annual rainfall somewhat lower, *viz.*, 26 inches, and consists of a vast expanse of rich alluvial soil considered to be one of the best in the Punjab. The Dhak and Manjki tracts, which lie towards the south of this district, and the Sirwal tract just to their north, are the most suitable for the production of a sugarcane crop about 85 per cent of which crop is irrigated.

(*b*) *Agricultural practice.*—The Jullundur district is dependent very largely on well irrigation by means of Persian wheels, and the crop rotations generally followed are :—

1. Wheat—>Maize—>Cotton—>*Senji*—>Sugarcane.
2. Wheat—>Maize—>*Senji*—>Sugarcane.
3. Wheat—>*Chari, Guara*—>Sugarcane.

Farmyard manure is generally applied to maize and cane in the first rotation and to maize or *chari-guara* in the 2nd and 3rd rotations respectively, the usual rate of application being from 150 to 300 maunds per acre. In some localities ammonium sulphate applied to the various fodder crops, or to the cane itself, has been used with marked success, and Co. varieties invariably give the best returns when conditions of cultivation, irrigation and manuring are favourable.

Zamindars have now learnt to appreciate the necessity of an adequate supply of manure, and since the quantity of farmyard manure available is limited, castor cake has been tried in some places with success.

In the Hoshiarpur district most of the cane is unirrigated, being grown under '*barani*' or '*sailab*' conditions, although there is an innundation canal known as the

rapidly to adopt improved varieties once he is convinced of their superiority and the higher profit accruing to himself by so doing.

In the Sialkot district, where, as late as 1929-30 the chief varieties grown were the local canes, Dhaulu, Katha, Kahu, or Maitku, the Coimbatore varieties have made rapid headway; in 1932-33 the last year of the survey, Co. 205, Co. 223, Co. 285, and Co. 290, were largely grown, and there is every indication that the zamindar is only too willing to replace low yielding indigenous varieties by better types, to the extent that seed of the latter is available.

(c) *Period of optimum ripeness.*—The ripening period generally extends from the middle of December to the end of March, although local zamindars start crushing for *gur* manufacture a month earlier.

It will be seen from Table XXVI that Dhaulu is an early ripening variety, and so may be judiciously employed to assist earlier crushing. None of the Co. varieties ripens as early as Dhaulu. Co. 285 and Co. 290 are not ready till December, so the introduction of such types is obviously necessary if the crushing season is to be extended. The types chosen must, however, be frost resisting as far as possible.

If these canes are kept standing beyond the end of March, speedy deterioration sets in, except when the winter is unduly prolonged, as was the case in 1930-31, when ripening was considerably delayed in consequence.

It is possible now by a correct selection of types to assure a crushing season of 120 days extending from the first week of December to the last week of March (Table XVII).

Quality of canes.—The analytical data on the different varieties of cane investigated during the survey are shown in Tables XVIII to XXIV, the figures given being as in the case of the south eastern Punjab, the averages of those found during the period of optimum ripeness. It will be observed that, with the exception of those canes which suffered from disease, such as red rot, or had been affected by frost at the time of their maximum ripeness, the composition of the juice varied only within narrow limits, and may be said to have remained practically constant in different seasons. The chief factors responsible for varying tonnage yields are the soil, cultivation, manuring and the effect of the seasons.

Thus the yield of Co. 205 varied from a minimum of 11·9 to a maximum of 22·7 tons, that of Co. 223 from 15·6 to 20·2 tons, that of Co. 285 from 16·4 to 22·25 tons and of Co. 290 from 16·7 to 21·3 tons per acre.

Tables XXV and XXVI show at a glance information useful alike to the grower and the manufacturer.

(*d*) *Indigenous and Coimbatore varieties.*—In the following table are shown the average figures for all the local and Coimbatore varieties analysed at all the different localities during the period of the survey :—

Outturn in tons per acre

	Stripped cane	Juice	Total solids	Sucrose	Glucose ratio	Purity coefficient
Local . .	12·02	7·15	1·29	1·09	5·16	83·1
Coimbatore .	17·90	11·16	2·06	1·77	4·87	86·0

The advantages of the Co. varieties are more pronounced in this tract than in the case of the Karnal and Rohtak districts, the outturn per acre in stripped cane, juice, total solids and sucrose of the new varieties being more than 50 per cent in excess of the figures from the local varieties, as compared with an excess of only about 20 per cent in the South Eastern Punjab.

This smaller difference of 20 per cent. in favour of Coimbatore varieties in the South-Eastern Punjab is largely due to the influence of Suretha which is not only one of the best local varieties of the province but compares favourably with the improved new varieties. The low average glucose ratio of the new varieties in the Gurdaspur area is due to the inclusion of Co. 214 which has a very low glucose ratio *viz.*, 1·9, and which, but for its low yield would undoubtedly be one of the best early ripening canes.

The effect of frost on sugarcane

From a climatic point of view, the Punjab does not appear to be pre-eminently suitable for the cultivation of sugarcane, as it lies between 27° 39″ and 34° 2″ N. and experiences a range of temperature from below freezing point in December and January to a maximum shade temperature of 118°F. or more at Lyallpur in May and June.

During the ripening period cane shows a progressive increase in the sucrose content with a corresponding decrease in invert sugar or glucose which continues till the cane is mature.

The effect of frost at any time during this period not only checks ripening but reverses the above process, although not all varieties are equally affected, and some recovery may take place if the frost is not too prolonged or severe.

(*e*) *Local and Coimbatore varieties.*—Table XVI shows the comparative figures for the different local and imported varieties averaged over a number of years, and as the following figures indicate the new varieties are very superior to the local ones.

Outturn in tons per acre

	Stripped cane	Juice	Total solids	Sucrose	Glucose ratio	Purity coefficient
Local (Katha) .	15·80	9·01	1·71	1·43	2·1	83·1
Coimbatore .	24·09	15·68	2·89	2·45	3·3	84·6

As was found in the southern Punjab, the glucose ratio is higher for the Coimbatore than for the local varieties, and for the same reasons, *viz.*, owing to the inclusion of the inferior Co. 205, and here also, this cane is disappearing as better varieties become available.

3. The Sub-montane Tract (Gurdaspur and Sialkot districts)

This circle comprises the districts of Gurdaspur, Sialkot, Gujranwala and Amritsar and is one of the largest cane tracts in the Punjab, growing about one third of the total cane of the Province or about 5 per cent of that grown in the whole of ndia.

The soil of this circle is a medium loam of average fertility, although in some parts of the Gurdaspur and Sialkot districts, which constitute the sub-montane tracts, the soil is very badly drained, and alkali conditions are commonly met with in the Gujranwala and Amritsar districts. The rainfall which occurs mostly from July to September averages from 30 to 40 in. per annum, and increases towards the hills, while frost is of annual occurrence and damages the crop according to its intensity.

The riverian tracts of the Beas and Ravi rivers are especially noted for *sailab* canes, and only a few of the newer selected varieties such as Co. 205 and Co. 285, which can withstand water-logged conditions, can be grown in such localities; as a result of the environment however, these have become very soft and the yield varies greatly being very low, for example in the Pathankot Tehsil as compared with Batala further south.

(*a*) *Agricultural practice.*—As already noted Gurdaspur is one of the largest cane growing districts of the Province, most of the cane being produced under '*barani*' conditions although well and canal irrigation is also practised.

The '*barani*' area includes the *sailab* lands which are a very interesting feature of the district as regards the sugarcane crop.

The most common rotation followed on these lands is sugarcane—sugarcane, or sugarcane—wheat, farmyard manure being applied only to the cane.

In the Tehsils of Batala and Gurdaspur the usual rotation followed, both on canal and well irrigated lands is, wheat—maize—*senji*—cane, the manure being applied to the maize only as a rule, at the rate of about 200 maunds per acre, although when available a little is also applied before sowing cane.

The cultivators of this district, apart from those of the Batala Tehsil are, generally speaking very indifferent and take little pains to cultivate the fields properly, with the result that low yields of cane are a common feature.

Under such inadequate and superficial conditions of cultivation the cane plant develops a shallow and inferior root system, a condition intensified by an excess of moisture, with the result that the cane frequently lodges. The percentage of fibre thus increases and that of juice falls, and both quality and yield are therefore adversely affected.

(*b*) *Varieties of cane.*—The history of different cane varieties met with in the Gurdaspur district presents some interesting features.

During the first year of the survey in 1927-28, Yuba, Dhaulu, Katha, Co. 205, and Co. 223, were the chief varieties grown, with Kansar, Kahu, Reora, and Kenara to a lesser extent.

Yuba is a soft cane and was grown chiefly owing to its superior quality and high juice content. Owing to its susceptibility to attack from insects and diseases, however, it has gradually been displaced by Co. 205 and Co. 223.

Dhaulu was generally grown on a rich loam soil, having a good water supply, while Katha was, and still is, grown extensively under *barani* conditions. Katha owes its survival to the superior quality *gur* produced from it, and to the fact that it will withstand the effects of frost better than many other local varieties. Otherwise, owing to its low tonnage yield, and high fibre content it would have disappeared long ago.

Co. 205 owes its popularity to its being a thick skinned hardy cane, able to withstand frost, drought and water-logging, but it has the disadvantage of giving a low quality juice with a somewhat brackish taste.

Co. 223 is free from this defect and gives good yields, but it is soft and juicy and is thus liable to attack by insects and wild animals.

By the year 1929-30 Co. 285 had also become established at a number of places.

Succeeding years have seen a steady increase in the area under Coimbatore varieties, the extension apparently being limited by the supply of seed available, so that in 1931-32, Co. 213, and Co. 285 were grown extensively while Co. 205 and Co. 223 were losing favour. During succeeding years Co. 285 continued to be widely grown together with Co. 213, Co. 290 and Co. 300 while Co. 205 and Co. 223 had almost entirely disappeared. This obviously indicates that the zamindar is willing

Sugarcane may thus be divided into three groups depending on their reaction to frost :—

(*a*) Frost-resistant (unaffected or almost unaffected by cold),

(*b*) Semi-resistant [these include varieties which are either (1) slowly affected by frost or (2) quickly affected but also quickly recovering from its ill effects],

(*c*) Non-resistant (varieties which are quickly affected and which either fail to recover or recover very slowly).

It is most important therefore in the Punjab to select as far as possible frost-resistant varieties or the benefits of an otherwise good season may be largely nullified at a critical period if frost supervenes.

Special attention has accordingly been directed during these surveys to the collection of data which will enable different varieties of cane to be classified according to their capacity to resist frost and the following have been specially investigated :—

Desi.—Uba, Katha, Dhaulu, Lalri and Suretha.

Coimbatore.—Co. 205, Co. 213, Co. 223, Co. 270, Co. 281 Co. 285, and Co. 290.

Some account will now be given of the effect of frost on these canes.

During the first year's survey (1927-28) there was no frost in the Karnal and Rohtak districts, nor any of sufficient severity or duration in other districts surveyed to affect the cane.

In the succeeding sugarcane season, *i.e.*, 1928-29, very severe weather, with continued frost occurred at a time coinciding with the maturity period of the cane, and adversely affected its maturing throughout the Province.

In the year 1928-29 the minimum temperatures (in shade and at a height of 4 to 5 ft. above the ground level) recorded at Gurdaspur, Jullundur, and Karnal were 27·7°C., 30°C., and 38°C., respectively. (It must be remembered that the actual minimum temperature experienced by cane is always considerably lower than the minimum as recorded by the thermometer.) The dates on which frost actually occurred are shown below.

	December	January	February
Gurdaspur . . .	27, 29	7, 21-22, 31	1-2, 4, 6, 13, 15
Jullundur	27—30	6—10, 21—23, 31	1-2, 12
Karnal	6, 19-26, 31	1—3, 5—11, 31	1-2

The effect of sustained frost adversely affected both the physical condition of the canes and the quality of the juice. The leaves withered, buds were killed and the cane was rendered quite unfit for purposes of seed.

The effect on the quality of the juice was different according to the variety. Early ripening varieties suffered inversion of the sucrose, *i.e.*, conversion into glucose and a return to what might be considered a normal sucrose content was rarely attained.

This may be seen from the analyses of Dhaulu and Katha shown in Tables XXVII and XXVIII for the year 1928-29.

During mild frost in December and January, the sucrose-glucose ratio in the Coimbatore canes in general showed irregular fluctuations, indicating the possibility of recovery. Succeeding sharp attacks on January 31st, February 1st and 2nd, 1929, rendered future recovery out of the question however, except in the case of certain varieties which showed some improvement.

Of the three varieties, Co. 205, Co. 213, and Co. 223, which alone, amongst the Coimbatore canes, were available in a sufficiently large number of localities, Co. 213 in most cases showed almost complete immunity, being followed by Co. 205 and Co. 223 in this respect. If, however, we group together the number of cases in which these latter two canes showed either resistant or semi-resistant qualities there is little to choose between them.

In the South-Eastern Punjab mild attacks of frost appeared not to have affected the canes, but the severe attacks on 31st January and 1st and 2nd February 1929 did adversely affect them.

The early ripening variety, Dhaulu, and also Larli and Suretha at some places, however, were so badly affected that they were unable to recover, while Co. 205, a late ripener, in three cases out of four, and Co. 213 and Co. 223 in 50 per cent of the cases investigated recovered completely.

At the Gurdaspur Agricultural Station it was noticed that Co. 281, an early, ripener, is one of the best frost resistant canes, while Co. 285 and Co. 290, which ripen in January, were also able to recover from the ill effects of frost.

In the 1929-30 season cane in the Gurdaspur district suffered more from hail in October than from mild frost experienced later on, while no appreciable permanent ill effects were noticed in the Sialkot and southern districts.

In the central districts, *viz.*, Jullundur and Hoshiarpur, the weather was warmer during the ripening period than in the same period of the previous year, although there were 24 frosty nights. Severe frost from the 19th to the 21st January, however, caused a reduction in the sucrose content, but the canes on the whole recovered.

In 1930-31 frost occurred intermittently from early December till the end of February and its effects were intensified by the previous dry weather. The lowest temperatures recorded were 28°F. at Sialkot on 1st January 1931, 29·6°F. at Gurdaspur on 22nd December 1930, and 28°F. at Jullundur on 22nd and 26th December.

It has been observed that the degree of frost a cane can withstand is modified to some extent by the nature and moisture content of the soil, and that canes growing on light loams suffer less than those on stiffer soils. Furthermore an application of potassium nitrate as a manure conferred some degree of immunity.

In the Jullundur and Hoshiarpur districts the monthly average maximum temperature from May to April was higher, and the average minimum lower than in the two previous years. The Sirwal and Bet lands near Tanda experienced the heaviest frost of the season and Katha cane at Jabboal suffered heavily in early December, when its glucose content increased from 0·11 per cent on December 8th to 0·54 per cent on the 19th December. This and succeeding attacks so damaged the cane that the glucose content never recovered to its original low value (Table XXIX).

The Coimbatore varieties, however, particularly Co. 213, which ripened late, after the frost, showed but little ill effect, although Co. 205 in five cases out of fifteen, and Co. 223 in one case out of four succumbed. It may be pointed out, however, that in the case of Co. 205, the crop (ratoon and plant) at Jhingar Kalan (fig. 9) and Bhondian as in the case of Co. 223 at Rasulpur experienced the sharpest frost in the district, while Co. 205 at Lahrara was infested by Pyrilla (fig. 9).

The winter of 1931-32 was comparatively mild throughout the Province, the lowest temperatures in the area surveyed being 30°F., 33°F. and 30·5°F. at Gurdaspur, Sialkot and Jullundur, respectively, and canes suffered very little damage beyond a temporary set back in some cases in February.

The winter of 1932-33 was unusually long with severe frosts at Gurdaspur and Sialkot from early December till the end of January, but these were tempered to some degree by occasional rain.

A noticeable effect of the prolonged cold was that most of the canes affected by it recovered in February or March and it appears that the injury caused by frost is aggravated if it continues very late in the season, when it is usually rapidly succeeded by abnormally warm weather.

When, however, moderately cold weather succeeds hard frost, the affected canes appear to have a better chance of recovery.

These conclusions are confirmed by observations made in the Jullundur and Gurdaspur districts in 1930-31, where, at many of the places surveyed Co. 223 ripened as late as the end of March, while at the Agricultural Station, Gurdaspur, Co. 223 (both the manured and unmanured crops) ripened as late as April (Tables XXX and XXXI and Fig. 12).

Similarly in 1932-33 at Chandowal, Katha, an early ripening variety, attained its maximum purity in the first week of April (Table XXXII and Fig. 2).

In the Jullundur and Hoshiarpur areas a timely fall of 2 in. of rain in the last week of December and early January succeeding a prolonged drought somewhat mitigated the effects of 28 nights of frost in January and February.

The bad effects, however, were most noticeable on Katha and Co. 300, both early ripening canes and caused a set back of a month in the crushing season.

Other varieties also received a temporary set back, particularly Co. 213 at Nakodar, Co. 205 at Miani Afghanan and Khurdpur, and Co. 285, Co. 301 and Co. 313 at Jullundur, while Co. 281 again showed the best resistance.

From these observations made over a period of six years it appears that the capacity of canes to escape permenent damage by frost depends in the first place on the intensity and duration of the attack, and is also related to the climatic conditions both before and after the same. Furthermore there is a greater likelihood of canes recovering from severe frost early in the season than there is from frost later on when the canes are ripe or nearly so. Generally speaking it may be observed that no variety is perfectly immune to the ill effects of frost under all conditions. A cane's behaviour as a resistant, semi-resistant or non-resistant type during any season will be determined by the local conditions prevalent at the time. Thus we find every variety, in canes where the number of observations have been sufficient, exhibiting the behaviour of all the above three types. A few selected canes are illustrated in Figs. 1—16.

The condition of the cane before frost occurs is an important factor in relation to the effect produced. Healthy canes unaffected by disease or previous drought will be more likely to recover than those which have been adversely affected in these respects. Thus a cane subjected to a combined attack of frost and Pyrilla will seldom recover, as was seen in 1930-31, when almost all varieties examined in the village of Lehrara in the south Punjab were attacked by Pyrilla, and mild frosts which supervened in December or subsequently proved fatal (Tables XXXIII—XXXV, Figs. 3, 5 and 9). Similarly in 1932-33, Co. 213, Co. 223, and Co. 300 suffered badly from red rot at Raja Sansi with the result that when frost followed they were never able to recover and the juice was of a disagreeable odour (Tables XXXVI—XXXVIII).

The effect of irrigation and rain in moderating the effect of frost is well known.

If the cane crop receives water immediately preceding or at the beginning of the onset of frost it either does not suffer at all or if it does it can recover in course of time with little worse effect than a delay in the time of maturity.

For example in 1929-30 in the Jullundur district apart from the mild frost at the end of November each subsequent frost was preceded by rain with the result that the crops did not suffer to any appreciable extent, while on the other hand canes attacked by Pyrilla appeared to improve, as a result of the insect having been dislodged from the leaves by rain and subsequently killed by the intense cold. Conversely the bad effect of frost in the absence of water is illustrated in the case of Katha canes at Khudda (*sailab* lands of Hoshiarpur) which did not suffer to so great an extent from the severe attack of frost in 1928-29, as it did from a comparatively

mild attack in 1930-31 (Tables XXVIII and XXIX). The explanation of this differential behaviour seems to lie in the fact that the locality received more than 5·35 in. of rain in 1928-29 distributed as shown below while in 1930-31, there was a dry period lasting practically from October to December, and a fall of 1·03 in. of rain in January did not prove sufficient to mitigate the ill effects of frost in the previous dry months.

	Oct.	Nov.	Dec.	Jan.	Total
1928-29	0·21	2·52	1·78	0·84	5·35
1930-31	*Nil*	*Nil*	0·15	1·03	1·18

An illustration of the beneficial effect of rain not only in mitigating the ill effect of frost but also in prolonging the crushing period of cane may be seen on referring to Table XI. Katha is an early ripening, semi-resistant cane, inclined to succumb to a severe attack of frost. The frost in 1930-31 was one of the severest during the period of the survey and yet the cane withstood it successfully at Jhabianwala near Jullundur city, because, during that year, rain and frost invariably alternated with each other. As will be seen 14 frosty nights from the 8th to 12th and from the 19th to the 27th of December affected the cane adversely, both by lowering its purity coefficient and increasing the glucose ratio. The injury to cane due to further attacks of frost on the 1st and 2nd January would very likely have been more severe from what we know of similar cases, but for the mitigating effect of 0·62 in. of rain on the 29th January. A fall of 1·62 inches of rain from the 21st to the 25th of January successfully counteracted the ill effects of eight frosty nights, on six of which the lowest temperatures of the season were recorded. This is evident from the fact that inversion of sucrose was negligible. Comparatively milder attacks of frost on the 29th and 30th of January preceded as they were by 1·62 inches of rain from the 21st to the 25th of January were unattended by any ill effects. Further rain in February, although it did not produce immediately favourable effects, was followed by rain in March, and improved the cane so much that on the 11th of March it attained the highest purity and lowest glucose ratio of the season.

Other similar harmful effects of frost without irrigation may be seen in the case of the canes at Jhingar Kalan (Tables XLI to XLIII), while the beneficial effects of irrigation are well shown in Tables XLIV relating to the Government Agricultural Farm at Jullundur.

The village of Rasulpur near Tanda Urmur on the Jullundur-Mukerian line usually grows its cane under well irrigation, but in 1930-31 the Co. 223 crop reserved for analysis received no water during the period of frost owing to the well from which it was irrigated being out of action. This factor, combined with an absence of rain in October and November injured the cane beyond recovery (Table XLV).

On the other hand, in the season 1931-32, when long continued frost occurred the same variety of cane at the same place received normal irrigation and matured in a normal manner (Table XLVI).

During exceptionally cold weather, almost all varieties are affected to some extent, although the resistance to moderate cold varies. Tables XLVII and XLVIII show the distribution of different varieties of cane (*viz.*, frost-resistant, semi-resistant, and non-resistant) in all the localities surveyed. As will be seen, this presentation is the result of a consideration of the behaviour of different varieties of sugarcane in 384 individual cases. It also shows that of the *desi* varieties non-resistant types of cane constitute about 37 per cent of the whole and the worst sufferers from frost were Katha and Dhaulu, followed by Suretha and Lalri. Of the indigenous varieties Lalri is one of the best frost-resistant types. Of the Coimbatore varieties, Co. 270 and Co. 281 may be considered resistant. Semi-resistant types, which will resist mild frost completely in most cases and only succumb under exceptionally severe attacks are Co. 213, Co. 285 and Co. 290, while Co. 205, and Co. 223 are definitely semi-resistant, Co. 205 * being slightly less so than Co. 223.

Thus on the basis of data available, the Coimbatore varieties may be arranged as follows, in order of decreasing resistance to frost:

Co. 270, Co. 281, Co. 285, Co. 290, Co. 213, Co. 223 and Co. 205.

Other varieties, *viz.*, Co. 300, Co. 301, Co. 312 and Co. 313 appear to be good frost, resistant canes, but the number of observations made on them is not yet sufficient to enable a definite expression of opinion to be given.

Diseases and pests

During the period covered by this survey the effects of a number of diseases and pests were studied, the chief among the later being, Pyrilla, Aleurodidae, top borer, stem borer, pyrallid borer, and white ants. Mosaic disease and red rot were also met with, but not in a virulent form.

Smut was particularly noticed attacking Katha canes at Nakodar in Jullundur, while aleurodidae and pyrallid borer were chiefly confined to the Gurdaspur circle, other diseases being more or less common to all the localities under survey.

Locusts

During August and September 1929 locusts did considerable damage to the cane crop of the Southern Punjab and central districts. The destruction of the green leaves causes great disturbance to the metabolic processes (elaboration of juice and carbohydrates) in the growing plant with the result that very poor yields were obtained in the affected areas.

* It must be remembered, however, that Co. 205 is a cane primarily meant for '*barani*' or '*sailab*' lands and on that account it will suffer more from the ill effects of frost than irrigated canes. This is a very likely reason for its position after Co. 223 in the above list.

Shoot and top borers

These pests were fairly active in all the districts surveyed, but especially destructive in the Southern Punjab during the 1930-31 season when the ratoon crops showed a greater susceptibility.

Pyrallid borer

This pest caused great damage to the cane crop of Gurdaspur in the 1931-32 and 1932-33 seasons, and the canes in the Bet areas suffered particularly in the former season.

Owing to the pith of the cane being attacked and eaten the stem becomes weak, growth is stopped, and the burrows made by the borers frequently become infested by red rot.

An analytical comparison of healthy canes with those afflicted by this pest as given in Table XLIX, is most instructive.

As is seen from this table the sucrose content was diminished by about 33 per cent in the diseased canes, while glucose increase from 300 per cent to 400 per cent. It is difficult to clarify the juice obtained from diseased canes, which remains a deep yellow colour inspite of all ordinary clarifying agents, while the *gur* obtained from them is of an inferior quality.

Pyrilla

This pest was commonly found throughout the Punjab, and was responsible for serious damage wherever it appeared, although the central districts suffered most. In the 1930-31 season it was prevalent to such a degree that it was difficult to find any cane unattacked, and some idea of the extent of the depreciation of cane caused thereby may be seen from Table L which gives comparative data for the average yields which were obtained in the Southern Punjab for the year in question and the preceding year, when the crop was practically free from Pyrilla.

These figures are self-expanatory and illustrate the enormous damage which this pest can cause.

Pyrilla was generally found to be the most prevalent pest in the Jullundur and Hoshiarpur districts, one of the most afflicted villages seen being Shahbazpur in the Bet lands.

One plot of Co. 223 at Kothran which was badly attacked in the season 1929-30 gave the following figures on analysis.

Percentage on cane				Glucose ratio	Purity coefficient
Juice	Total solids	Sucrose	Glucose		
64.8	7·7	5·70	·81	15	74

The year 1930-31 was favourable for ascertaining the effects of this pest, as there were four varieties of cane, Co. 213, Co. 223, Co. 281 and Co. 285 all badly affected by Pyrilla on fields 2 and 3 of the Government Agricultural Farm at Jullundur, while in fields 13 and 14 in another block not far away the same varieties of cane (except Co. 223) were comparatively free. It was found that although the Pyrilla-affected canes gave a greater percentage of juice and glucose, the healthy crop gave more sucrose and total solids (Table LI).

The unaffected crop here gave 27 per cent more sucrose than the affected one, but the latter showed a glucose ratio three times greater than the former.

Co. 223 appeared however to be more susceptible to attack in both these areas.

This strange phenomenon of immunity and attack in almost adjacent areas appeared to be due to the fact that the crop in fields 2 and 3 under direct cultivation was a much heavier and a better one than the crop in fields 13 and 14 under tenant cultivation—the respective yields being 30·2 and 21·6 tons per acre and so provided better conditions for the protection and multiplication of the insects. Experience has shown that rain can destroy this pest and prevent undue damage if it falls at the right time, but it is, of course, a factor which cannot be controlled.

Conspicuous features of the effects of Pyrilla are that the quality of the crop suffers more than the tonnage yield, and that certain varieties appear to be more susceptible to attack than others. For example Katha, Co. 205 and Co. 285 appear to be more immune than are Co. 213 and Co. 223.

Aleurodidae

Aleurodidae are insects, the nature of whose attacks and effects are similar to those of Pyrilla. It has been found to be prevalent chiefly in the Gurdaspur district in all years of the survey except 1931-32.

White ants, rats and jackals

The depredations of white ants are well known, and they appear to show some preference for Co. 281, Co. 223 and to a certain extent for Co. 290, although no variety is immune.

Rats are serious enemies of the cane crop, and find shelter in heavy crops which have lodged, although lodging can be mitigated to some extent by growing the cane in trenches, which helps to prevent lodging and thus indirectly checks the rat menace.

Jackals are chiefly found in the Bet lands throughout the Province.

Smut and mosaic disease

Smut, which is a fungoid disease, has been noticed particularly in the Jullundur district but does not appear to have done any serious damage.

Mosaic, a virus disease, has the reputation in tropical countries of being responsible for great damage. Evidence of the disease which is more common in ratoon

crops is afforded by the leaves, which present a mottled appearance due to the formation of translucent yellow spots.

This disease was specially studied at Gurdaspur for three years and, as the figures in Table LII indicate, did not appear to cause any material deterioration in the composition of the juice, nor was the tonnage yield appreciably affected.

Red rot (*Colletotrichum felcatum* Went)

A serious attack of this disease which occurred during the season of 1932-33, on the cane crop of Rajah Sansi in the Amritsar district was studied.

All the varieties cultivated, *viz.*, Co. 213, Co. 223, Co. 285, Co. 290, and Co. 300 suffered badly and as a consequence the canes never reached their maximum maturity and deteriorated seriously after the attack, with the result that no *gur* could be made and the whole crop had to be burnt. Table LIII of analytical data obtained before and after the attack shows the effect of this disease and it will be noted that Co. 223 was damaged most and Co. 285 was the least affected. It may be noted that Co. 285 has proved as a rule to be one of the best frost and disease resisting varieties so far introduced.

Flowering of sugarcane

Sugarcane does not usually flower in the Punjab although under certain favourable but undefined conditions Coimbatore canes do, but the old varieties such as Dhaulu and Katha hardly ever do so.

The zamindar usually regards this phenomenon as inauspicious and believes that flowering signifies a deterioration in the quality of the cane. If, however, we examine the analytical figures for the juice from flowering and non-flowering canes of the same variety (Table LIV) it will be seen that contrary to this belief the flowering canes are superior ; they contain more sucrose, less glucose, and consequently have a lower glucose ratio and a higher purity coefficient.

The average figures for these four factors for Co. 205 in flowers was found to be 16·6, 0·61, 3·7 and 85 respectively, and 15·5, 0·78, 5·0 and 83 for Co. 205 not in flowers. Corresponding data for Co. 285 are shown in the table below :—

	Sucrose	Glucose	Glucose ratio	Purity coefficient
Flowering	17·0	0·36	2·1	88
Flowerless.	16·5	0·40	2·4	87

The mild weather conditions of 1931-32 were very favourable for the cane crop and for observing the effects of flowering. Both Co. 205 and Co. 285 flowered at a

number of places in the Jullundur, Hoshiarpur, Ludhiana, Gurdaspur, and Gujranwala districts and a reference to Table LIV shows that the average weight of cane in flower was greater than that of a similar non-flowering cane, the figures being 580 grams against 442 grams for Co. 205, 803 grams against 616 grams for Co. 285, the excess weight averaging 30 per cent. It will be further noticed that flowering (or arrowing) does not affect the quality of the juice obtained, as the percentages of juice for the two types mentioned in flowering and flowerless cane were 57·9 and 59·2 for Co. 205, and 61·6 and 62·2 for Co. 285.

Table LV shows the monthly rainfall figures for the years 1927-28 to 1931-32 for the districts of Jullundur and Hoshiarpur, from which it will be observed that the rainfall and temperature during the four months, September-December, appeared to have a marked influence on the maturity and incidence of flowering in canes. Heavy rainfall during these months delayed maturity, while scanty rain accelerated it and checked vegetative growth, thus conducing to conditions favourable for flowering.

Abnormally high rainfall in the 1928-29 and 1929-30 seasons prevented the cane crop from maturing until as late as March. In the 1927-28 and 1931-32 seasons rainfall was deficient and the flowering of canes profuse.

From these observations it can be stated with reasonable confidence that not only are the fears of zamindars on the appearance of flowers on cane groundless, but that the flowering crop is usually superior, and gives better yields with a lower glucose ratio and a higher purity coefficient.

Ratooning

The new imported varieties of Coimbatore canes lend themselves very favourably to ratooning, a practice which is now becoming common with the gradual disappearance of the old local varieties for which this practice was not suitable and seldom practised except in years of fodder scarcity when the entire cane crop was needed for feeding animals.

It was generally observed that yields from the local varieties ratoon crop, were not equal to those from the parent crops, while the reverse generally held good with Coimbatore varieties.

Ratooning, therefore, offers certain advantages to the zamindars, as the usual operations necessary, prior to sowing canes are eliminated, and there is a saving of the cost of seed. Furthermore the ratoon crop ripens earlier, and owing to its well established root system it is better able to withstand unfavourable weather conditions.

Such a combination of advantages is, therefore, rendering the practice increasingly popular, and it was noticed in the early years of the survey that the zamindars in the Karnal and Rohtak districts were rapidly adopting it. In the Bets of Beas the practice has also become common, and as conditions in this locality are very favourable for a *barani* crop the local zamindar prefers a ratoon to a plant crop; in fact in the riverian tracts of the Beas, ratoon crops ten years old have been seen.

The general popular belief is that the yield increases for two or three years, remains stationary for an equal period and then begins to decline. It is replaced by a plant crop when the cultivators find it no longer pays.

Experiments carried out at the Jullundur Agricultural Station, for a number of years have given results shown in Table LVI.

These figures show that in this case, Co. 213 whose yields steadily declined was less suited for ratooning than Co. 223. Co. 205 is considered to be the type most suitable for ratooning.

Observations made at Miani Afghanan (Hoshiarpur) in two successive seasons showed that both Co. 205 and Co. 285 were suitable for ratooning as is indicated in Table LVII.

The ratoon crop from both varieties is seen to have given higher yields than the original plant crop and the quality was also maintained.

The practice, however, presents one serious disadvantage in as much as the presence of the crop on the land throughout the year offers conditions of food and shelter favourable for the development of the numerous pests which prey on the crop.

Consequently if the cane crop of the Punjab is not to suffer undue damage on this account, extensive ratooning is not to be recommended without adequate measures of insect control.

Fibre

Fibre is an important constituent of the cane plant, as it provides the framework with texture and support, without which it could not stand.

Lodging is one of the factors which greatly affects the tonnage and quality of cane, with larger applications of manure, better irrigation facilities, and more up-to-date methods of cultivation, heavier crops are now obtained and a cane with a low fibre content will lodge at a much earlier stage of vegetative growth than one not so handicapped.

Co. 205 contains about 18·5 per cent of fibre and is hence capable of withstanding drought and rain better than most other varieties, and this helps to explain why it is such a heavy yielder.

Similarly Co. 285 with a fibre content varying from 16·5 per cent in Jullundur to 17·7 per cent in Gurdaspur, is well suited to a wide range of differences of climate and conditions of cultivation, while the high fibre content of Katha may explain its survival as one of the hardiest of the indigenous varieties.

Such canes are also appreciated by the Zaminder as they afford him an adequate supply of fuel for *gur* making. Table LVIII gives the percentages of fibre in some canes grown at Jullundur and Gurdaspur.

It is noteworthy that most of the local varieties have a high fibre content, a fact noted by Barnes (*loc. cit.*) who gave the following figures :—

Variety	Per cent fibre
Dhaulu	20·60
Katha	23·57
Kansar	18·33
Teru	19·39
Kahu	13·54
Ponda	10·60

(The last two are soft chewing canes and are chiefly cultivated near towns.)

As explained above a high fibre content has advantages, but is not in itself a desirable feature.

Most of the Java canes show a fibre content of only about 12 per cent, and it is evident that if better methods of cultivation and pest control were possible, and lodging could be avoided a low fibre cane would be preferable to one with a high fibre content.

Effect on the cane crop of withholding water from October onwards

In the season of 1932-33, which as we have previously seen was characterised by prolonged frost in December and January, it was decided to study the effect on the cane crop of withholding water during October and subsequent months.

For this purpose separate fields of cane each under one variety were selected and divided into three portions each about 50 feet wide and 50 feet long. The two outer portions received normal irrigation while the central one was left without irrigation, and in order to eliminate the effect of lateral seepage strips from 10-15 ft. wide on either side of the central portion were omitted from the calculations.

The varieties selected for test were Co. 213 and Co. 223 at the Jullundur farm and at Jallowal in the Jullundur tehsil, Co. 213 at Baiyanpur near Sonepat and Co. 223 at the Hansi Agricultural Farm.

The results of the analyses from these trials are shown in Table LIX as the averages of figures obtained during the period of ripeness, and the following conclusions are deduced from them as the result of withholding irrigation :—

(*a*) The yield of both Co. 213 and Co. 223 was adversely affected.

(*b*) The quality of cane was not materially affected.

(*c*) The percentage of juice showed no significant differences.

(*d*) The fibre and glucose percentages were slightly less in canes receiving less water.

(*e*) The canes remained shorter but became thicker.

Effect of artificial manures on sugarcane

Although the survey under discussion was not primarily concerned with the effect of manures on cane, some specific observations were made in 1930-31, at the Gurdaspur Agricultural Station to ascertain the relative effects of certain artificial manures on the analytical data obtained from Co. 223.

Sugarcane is an exhaustive crop and in any intensive system of rotations in which it is included, the necessity for adequate manuring is an axiom of good husbandry.

While therefore the problem of the effects of manures on cane and the economic aspects of their employment forms by itself a separate enquiry, certain data is given here as illustrating the results obtained on Co. 223 with the following artificial manures :—

Manure	Rate of application
Potassium nitrate	2 Mds. per acre
Super-phosphate	1½ Mds. per acre
Ammonium sulphate	1½ Mds. per acre
Ammonium phosphate	1½ Mds. per acre

Half the dose was applied on May 15th, 1930, and the other half on June 24, 1930, just before the rains.

Table LX shows the averages of data obtained from the trial crops analysed during the 1930-31 season.

The highest yields were obtained from canes manured with potassium nitrate and ammonium sulphate respectively.

It was intended to repeat these trials in the following year, but it became necessary to ratoon the experimental crops owing to lack of water, and so the ratoon crops were subsequently analysed with the results shown below, which correspond with Table LX :—

Showing effect of artificial manure on Co. 223 ratoon crop

Potassium nitrate	15·3	1·41	0·064	1·62	62·0	9·2	0·42	10·6
Super-phosphate	12·7	1·16	0·052	1·33	60·9	9·1	0·41	10·5
Ammonium sulphate	16·1	1·48	0·068	1·71	60·8	9·2	0·42	10·6
Ammonium phosphate	12·8	1·18	0·047	1·33	60·0	9·2	0·37	10·4
Control	12·3	1·13	0·049	1·28	60·0	9·2	0·40	10·4

In the year 1932-33, these trials were repeated using Co. 285 as the test plant crop and the results are given in Table LXI.

The results of the three years' observations indicate that the canes in question respond best to potassium nitrate and ammonium sulphate in regard to yields Ammonium sulphate and Ammonium phosphate, however, delayed ripening to some extent, while potassium nitrate and super-phosphate had no such effect.

Furthermore the artificials employed only affected the tonnage yields and were without influence either on the quality or quantity of juice obtained (apart from the ash content) or on the percentage of fibre in the cane. Another interesting feature was the fact that canes treated with potassium nitrate showed a greater resistence to low temperatures ; their juice showed a lower freezing point and a higher ash content, while the fibre content was unaffected.

These results have been confirmed by manurial trials carried at the Hansi Agricultural Farm during the last two seasons of the survey, when ammonium sulphate and ammonium phosphate, although showing increased yields, caused no difference in the quality of the juice.

Summary

1. The survey here described was conducted for four years in the Rohtak-Karnal area and for six years in the Jullundur and Gurdaspur Circles.

2. The Coimbatore varieties have on the whole given better yields of cane and sucrose per acre in all the centres surveyed.

The average figures for all localities are shown in Tables LXII and LXIV.

The sugar industry in the Punjab must depend for its success very largely on these new varieties, although Suretha among the indigenous canes was still a very successful cane in the Southern Punjab.

3. The quality of the Coimbatore canes has shown a steady improvement since 1928-29, mainly due to the introduction of new and better types.

Until 1931-32, Co. 213, Co. 285 and 290 were undoubtedly the best canes found and to a large degree the improvement in sugarcane production can be traced to them. Co. 281 and Co. 285 are the next best. During the last season, however, four new types of cane, Co. 300, Co. 301, Co. 312, and Co. 313, gave still better

results. The first of these, in addition to its other qualities, was also immune to attack by Pyrilla, due perhaps to the presence of a growth of hairy bristles on the under surface of its leaves. Both in regard to yield and quality, Co. 300 has proved to be the best cane in the Gurdaspur Circle, while the last three types have so far only been introduced in the Jullundur area (Tables LXII-LXIV and XVI).

4. Average figures for the yields of cane per acre during the period of the survey show that, of the localities surveyed, the Southern Punjab is, taking all factors into consideration, the best suited for sugarcane production.

On the other hand if we consider the amount of sucrose obtained from a normal crop per acre the Jullundur and Hoshiarpur districts, in spite of a somewhat lower tonnage yield, have given the best results. It must be remembered, however, that some of the new Coimbatore varieties which are responsible for the improvement of cane in the latter area were not included in the survey of the former tract, which terminated in 1931. Further analytical investigation may show that these newest varieties are doing still better in the more suitable south-eastern portion of the Province.

5. With the introduction of new varieties the period of optimum ripeness, during which cane is available for crushing has been considerably extended, although it varies in different localities (Tables VIII, XVII and XXVI). The average period as determined during the survey was 118 days for Rohtak and Karnal, 130 for Gurdaspur and 135 for Jullundur and Hoshiarpur, although some slight modification of these figures may be necessary, owing to the earlier termination of the survey in the Rohtak and Karnal area.

Most of the Coimbatore varieties do not ripen before the first week of December, so in order to increase the length of the crushing season, or for early crushing, local varieties such as Katha, Dhaulu and Lalri, will still be required. It is therefore very desirable that efforts be made to produce new Coimbatore varieties which, in addition to their existing desirable qualities, will also be early ripeners, since in view of the usual agricultural practice followed in the Punjab any lengthening of the crushing season beyond the end of March is not desirable.

No single variety can, however, be expected to have a period of optimum ripeness of more than, if as much as, 100 days, and so a judicious blending of types with graded maturity is necessary for a long crushing period.

6. It is not possible to form any systematic and exact estimate of the extent of damage caused to the cane crop by frost, insect pests and disease, since the incidence and intensity of these factors vary widely from year to year.

Local varieties such as Katha and Lalri may, however, be classified as semi-resistant to frost, Co. 281 and Co. 285, as more or less resistant, while Co. 223 is usually damaged.

It is too early yet to offer a decided opinion on the reaction of Co. 300, Co. 301, Co. 312, and Co. 313 to frost as the observations so far made require to be confirmed in the future.

The very succulent leaves and low fibre content of Co. 223, and Co. 290, render these types particularly susceptible to injury by insects and disease.

7. The flowering of canes, which has been observed to occur only in the case of Coimbatore varieties, marks the end of vegetative growth and does not indicate any deterioration in quality as has been supposed by some cultivators ; on the other hand canes in flower usually indicate heavier crops than do flowerless canes. It has been observed that scarcity of rainfall during September, October, November and December is conducive to conditions favourable to flowering.

8. Coimbatore varieties are well adapted for ratooning and therefore with their introduction the practice of ratooning is becoming popular, specially in the Bet or riverian tracts of the Province. The presence of sugarcane in the soil throughout the year, however, supplies a steady source of food to insects and pests common to this crop. A close watch on a ratoon crop is, therefore, necessary if the multiplication of these diseases and pests, to the great risk of injury to neighbouring healthy crops is to be avoided.

9. Sugarcane, particularly the new varieties, shows, under normal conditions, a definite response to the application of artificial manures, provided other features, such as irrigation, cultivation, etc., are attended to.

Of the manures tried ammonium sulphate and ammonium phosphate appear to give the best results as regards yields, although there is no appreciable difference in the quality of the juice obtained from manured and unmanured crops of the same variety.

10. Withholding irrigation from October onwards results in decreasing the yield of cane per acre, although the composition of the juice is not affected to any appreciable extent.

REFERENCE

Barnes, J. H. (1918). *Agric. Res. Inst., Pusa Bull.* No. 69.

Tables I to LXV

Figures for total solids, sucrose and glucose given in these tables, were originally determined in juice and then calculated on cane on the basis of extractable juice. Thus they do not represent the absolute quantity of these constituents present in the cane. This fact should also be remembered in considering the outturn of these substances per acre or per ton of cane.

During the survey over 4,500 analyses were carried out and as it is not convenient to present the results of the whole of these, data presented in Tables I to XXVI and some of the other tables are based on the averages of the figures for the different constituents of canes during the period of " optimum ripeness ". Each variety of cane was analysed at fortnightly intervals, generally from the beginning of November to the middle of April.

TABLE I

Average composition of Lalri during period of ripeness (Karnal and Rohtak districts)

Year	Locality	Weight of stripped cane in tons per acre	Percentage on cane				Glucose ratio	Purity co-efficient
			Juice	Total solids	Sucrose	Glucose		
1927-28 .	Shamaspur . . .	28·50	48·24	8·90	7·62	0·035	0·46	85·6
	Kalupur . . .	34·86	44·22	8·52	7·39	0·039	0·52	87·8
	Sheikhupura . .	23·77	48·87	10·00	8·42	0·025	0·30	84·3
Average for the year.	..	**29·04**	**47·11**	**9·14**	**7·81**	**0·033**	**0·42**	**85·4**
1928-29 .	Charao . . .	14·17	44·51	8·95	7·17	0·21	2·30	80·1
	Budhshyam . . .	22·48	43·37	8·57	7·20	0·11	1·52	84·0
	Shamaspur . . .	21·60	44·60	8·96	7·53	0·13	1·80	84·0
	Sonepat . . .	24·45	46·60	9·35	7·62	0·14	1·74	81·6
Average for the year.	..	**20·68**	**44·77**	**8·95**	**7·38**	**0·15**	**2·00**	**82·5**
1929-30 .	Sonepat . . .	14·27	55·20	10·89	9·33	0·06	0·70	85·6
	Machhroli . . .	19·98	61·40	10·42	8·01	0·12	1·45	76·9
	Jharautha . . .	12·85	57·19	11·01	9·14	0·11	1·26	83·1
	Shamaspur . . .	15·70	56·46	11·05	8·91	0·17	1·92	80·6
Average for the year.	..	**15·56**	**57·56**	**10·84**	**8·85**	**0·11**	**1·24**	**81·6**
1930-31 .	Mohammadabad . .	16·20	55·30	10·42	7·56	0·19	2·22	82·0
	Jatheri . . .	16·10	56·30	9·85	7·95	0·17	2·15	80·7
	Lehrara . . .	17·40	57·40	9·27	7·06	0·27	3·83	76·1
	Jaji	15·90	58·40	9·65	7·38	0·19	2·54	76·2
Average for the year	..	**16·40**	**56·85**	**9·75**	**7·74**	**0·21**	**2·70**	**79·4**
Average for four years	..	**20·42**	**51·57**	**9·67**	**7·94**	**0·12**	**1·57**	**82·1**
Average yield for the last three years	..	**17·55**	..	..	..	..	..	..

TABLE II

Average composition of Suretha and Dhaulu during period of ripeness (Karnal and Rohtak districts)

Year	Locality	Weight of stripped cane in tons per acre	Percentage on cane				Glucose ratio	Purity co-efficient
			Juice	Total solids	Sucrose	Glucose		
			Suretha					
1927-28 . . .	Shamaspur .	50·15	52·22	10·95	9·47	0·05	0·49	86·4
	Kalupur . .	32·80	53·00	9·68	7·87	0·11	1·44	81·3
	Sheikhupura .	45·40	56·40	11·02	9·22	0·04	0·39	83·5
Average for the year	. .	**42·78**	**53·87**	**10·55**	**8·85**	**0·07**	**0·73**	**83·9**
1928-29 . . .	Chirao . .	18·78	45·26	8·25	6·83	0·24	2·90	78·6
	Budhshiam .	32·25	48·57	9·67	8·23	0·09	1·16	85·8
	Shamaspur .	23·91	52·90	10·70	8·57	0·17	2·07	84·4
	Sonepat . .	24·15	51·14	10·00	8·35	0·25	2·90	82·4
Average for the year	. .	**24·77**	**49·44**	**9·66**	**8·00**	**0·19**	**2·10**	**82·8**
1929-30 . . .	Sonepat . .	26·31	60·69	11·37	9·41	0·10	1·02	82·8
	Machhrauli .	29·07	68·36	10·23	7·71	0·16	2·05	75·4
	Shamaspur .	16·62	60·33	11·67	10·02	0·22	2·23	85·9
Average for the year	. .	**24·00**	**63·13**	**11·09**	**9·05**	**0·16**	**1·80**	**81·6**

TABLE II—*contd.*

Year	Locality	Weight of stripped cane in tons per acre	Percentage on cane				Glucose ratio	Purity co-efficient
			Juice	Total solids	Sucrose	Glucose		
1930-31 . . .	Fatehpur .	22·10	66·40	10·89	9·01	0·23	2·56	82·7
	Jatheri . .	18·90	61·50	12·27	10·22	0·37	3·64	83·3
	Lehrara (Pyrilla and frost) affected	22·90	65·00	7·56	4·61	0·51	0·23	67·3
	Phusgarh .	19·60	52·10	9·79	7·40	0·23	3·10	75·6
	Jaji . .	14·50	57·60	10·21	8·27	0·20	2·41	80·9
Average for the year	..	**19·60**	**58·52**	**10·14**	**7·90**	**0·31**	**3·90**	**77·9**
Average of four years	..	**27·79**	**56·49**	**10·36**	**8·45**	**0·18**	**2·14**	**81·6**
Average yield for the last three years	..	**22·79**	..	..	..	..	..	..
			Dhaulu					
1927-28 . . .	Chhaparya .	26·0	57·25	10·80	9·05	0·04	0·48	83·8
1928-29 . . .	Khara (*baruni*).	25·18	45·10	8·14	7·22	0·14	1·75	89·1
Average of two years	..	**25·59**	**48·18**	**9·47**	**8·14**	**0·09**	**1·10**	**86·0**

TABLE III

Average composition of Co. 205 during period of ripeness (Karnal and Rohtak districts)

Year	Locality	Weight of stripped cane in tons per acre	Percentage on cane				Glucose ratio	Purity co-efficient
			Juice	Total solids	Sucrose	Glucose		
1927-28	Shamaspur	25·40	52·97	10·30	8·85	0·09	0·96	86·0
	Kalupur	36·30	52·67	10·29	8·65	0·18	1·31	84·0
	Jaurasi	23·10	51·10	10·49	9·32	0·05	0·58	90·0
	I. C. B. Farm	28·60	48·49	9·10	7·90	0·10	1·39	86·8
Average for the year	..	**28·30**	**51·31**	**10·06**	**8·68**	**0·11**	**1·20**	**83·5**
1928-29	Chirao	27·61	49·03	9·52	8·21	0·28	3·32	86·2
	Budhshiam	31·55	46·70	8·90	7·52	0·27	3·68	83·3
	Shamaspur	26·83	52·00	8·90	7·09	0·15	2·20	80·0
	Sonepat	21·75	51·86	10·00	7·80	0·71	9·20	78·3
Average for the year	..	**26·93**	**49·90**	**9·33**	**7·65**	**0·35**	**4·60**	**82·0**
1929-30	Sonepat	23·26	57·00	10·24	8·61	0·12	1·40	84·1
	Machhrauli	29·54	60·62	11·05	9·25	0·22	2·35	83·7
	Jharauntha	17·71	59·85	11·02	9·28	0·21	2·31	84·2
	Shamaspur	20·67	60·24	11·37	9·54	0·19	1·96	84·0
Average for the year	..	**22·80**	**59·43**	**10·92**	**9·18**	**0·18**	**1·96**	**82·2**
1930-31	Mohammadabad	18·60	52·80	10·08	8·77	0·21	2·43	86·4
	Lehrara	15·80	64·30	9·75	7·30	0·69	9·39	74·8
	Jaji	21·40	57·50	10·64	9·03	0·34	3·78	85·0
Average for the year	..	**18·95**	**58·21**	**10·15**	**8·37**	**0·41**	**4·90**	**82·5**
Average of four years	..	**24·25**	**54·71**	**10·16**	**8·47**	**0·35**	**4·13**	**82·6**
Average yield for the last three years	..	**22·90**	..	..	..	..	..	..

TABLE IV

Average composition of Co. 213 during period of ripeness (Karnal and Rohtak districts)

Year	Locality	Weight of stripped cane in tons per acre	Percentage on cane				Glucose ratio	Purity co-efficient
			Juice	Total solids	Sucrose	Glucose		
1927-28 . . .	Machhrauli .	40·10	59·1	11·82	10·80	0·03	0·24	91·4
1928-29 . . .	I. C. B. Farm .	30·22	52·8	9·19	7·35	0·16	2·30	80·2
	Budhshiam .	29·72	55·6	9·77	8·51	0·22	2·81	85·0
	Sonepat . .	25·44	56·3	10·17	8·69	0·22	2·51	84·4
Average for the year	..	**28·46**	**54·9**	**9·71**	**8·18**	**0·20**	**2·45**	**84·2**
1929-30 . . .	Sonepat . .	20·03	59·8	10·95	9·69	0·06	0·58	88·4
	Machhrauli .	28·61	67·0	12·53	11·09	0·09	0·81	88·5
Average for the year	..	**24·32**	**63·4**	**11·74**	**10·39**	**0·08**	**0·77**	**88·5**
1930-31 . . .	Fatehpur .	23·10	61·4	10·14	8·57	0·34	4·05	84·6
	Jatheri . .	18·40	63·4	10·70	9·25	0·30	3·31	86·4
	Phusgarh .	22·60	64·9	10·24	8·03	0·31	3·76	78·7
	Jaji . .	23·90	63·4	9·40	7·80	0·48	6·25	82·8
Average for the year	..	**22·00**	**63·3**	**10·12**	**8·41**	**0·36**	**4·30**	**83·1**
Average of four years	..	**28·72**	**60·2**	**10·86**	**9·45**	**0·17**	**1·80**	**87·1**
Average yield for the last three years	..	**24·93**	..	..	..	..	..	..

TABLE V

Average composition of Co. 223, Co. 210 and Co. 214 during period of ripeness (Karnal and Rohtak districts)

Year	Locality	Weight of stripped cane in tons per acre	Percentage on cane				Glucose ratio	Purity coefficient
			Juice	Total solids	Sucrose	Glucose		
		Co. 223						
1927-28	Shamaspur	26·90	59·47	11·48	10·40	0·08	0·79	90·6
1928-29	I. C. B. Farm	39·32	48·60	8·50	6·85	0·24	3·50	81·5
	Budhshiam	29·12	51·55	8·58	7·10	0·27	3·81	82·6
	Shamaspur	25·55	52·84	9·40	8·06	0·13	1·66	85·7
	Sonepat	28·26	49·03	8·25	7·50	0·08	1·08	84·8
Average for the year	..	**30·56**	**50·50**	**8·68**	**7·38**	**0·18**	**2·43**	**85·2**
1929-30	Sonepat	28·42	62·31	11·30	10·04	0·13	1·26	88·8
	Jharauthi	17·76	64·05	11·91	10·29	0·20	1·97	86·4
	Shamaspur	24·86	62·40	10·93	9·57	0·19	1·97	87·4
Average for the year	..	**23·68**	**62·92**	**11·38**	**9·97**	**0·17**	**1·71**	**87·6**
Average of three years	..	**27·05**	**57·63**	**11·18**	**9·25**	**0·14**	**1·52**	**82·8**
Average yield for the last two years	..	**27·12**	..	..	..	..	..	..
		Co. 210						
1927-28	I. C. B. Farm	19·96	52·51	9·26	8·06	0·06	0·78	87·0
		Co. 214						
1927-28	I. C. B. Farm	18·80	53·83	9·82	8·45	0·05	0·64	86·0

TABLE VI

Amount of juice and sucrose, etc., per acre (in tons) and per ton of cane (Karnal and Rohtak districts)

Variety	Year	Weight per acre				Weight per ton of cane		
		Stripped canes	Juice	Total solids	Sucrose	Juice	Total solids	Sucrose
Lalri . . .	1927-28 . .	29·04	13·70	2·65	2·27	0·471	0·091	0·078
	1928-29 . .	20·68	9·15	1·81	1·51	0·448	0·090	0·074
	1929-30 . .	15·56	8·96	1·68	1·38	0·576	0·108	0·089
	1930-31 . .	16·40	9·32	1·61	1·26	0·569	0·098	0·077
	Average . .	**20·42**	**10·32**	**1·94**	**1·58**	**0·516**	**0·097**	**0·079**
Suretha . . .	1927-28 . .	42·78	23·10	4·54	3·82	0·539	0·106	0·089
	1928-29 . .	24·77	12·22	2·40	1·98	0·494	0·097	0·080
	1929-30 . .	24·00	15·18	2·66	2·18	0·631	0·111	0·091
	1930-31 . .	19·60	11·47	1·98	1·55	0·585	0·101	0·079
	Average . .	**27·79**	**15·70**	**2·89**	**2·36**	**0·565**	**0·104**	**0·085**
Dhaulu . . .	1927-28 . .	26·00	13·35	2·81	2·36	0·513	0·108	0·091
	1928-29 . .	25·18	11·35	2·04	1·81	0·451	0·081	0·072
	Average . .	**25·59**	**12·35**	**2·43**	**2·08**	**0·482**	**0·095**	**0·081**

Co. 285 . .	1927-28 . .	28·30	14·56	2·94	2·46	0·513	0·104	0·087
	1928-29 . .	26·93	13·45	2·51	2·08	0·499	0·093	0·077
	1929-30 . .	22·80	13·54	2·53	2·10	0·594	0·111	0·092
	1930-31 . .	18·95	8·29	1·93	1·59	0·437	0·102	0·084
	Average .	**24·25**	**12·50**	**2·62**	**2·02**	**0·511**	**0·103**	**0·085**
Co. 213 . . .	1927-28 . .	40·10	24·95	4·78	4·38	0·591	0·118	0·108
	1928-29 . .	28·46	15·60	2·62	2·43	0·549	0·092	0·082
	1929-30 . .	24·32	15·50	2·85	2·53	0·634	0·117	0·104
	1930-31 . .	22·00	13·93	2·22	1·85	0·633	0·101	0·084
	Average .	**28·72**	**17·30**	**3·13**	**2·74**	**0·602**	**0·109**	**0·095**
Co. 223 . . .	1927-28 . .	26·90	16·00	3·10	2·80	0·595	0·115	0·104
	1928-29 . .	30·56	15·43	2·76	2·26	0·505	0·087	0·074
	1929-30 . .	23·68	16·55	3·00	2·58	0·629	0·114	0·098
	Average .	**27·05**	**15·99**	**2·95**	**2·55**	**0·576**	**0·105**	**0·093**

TABLE VII

Composition of juice from different varieties of cane—average of four years (Karnal and Rohtak districts)

Variety of cane	Weight of stripped cane in tons per acre	Per cent on cane of				Glucose ratio	Purity coefficient
		Juice	Total solids	Sucrose	Glucose		
Lalri	20·42	51·57	9·67	7·94	0·10	1·51	82·1
Suretha	27·79	56·49	10·36	8·45	0·18	2·10	81·6
Dhaulu	25·59	48·18	9·47	8·14	0·09	1·11	86·0
Co. 205	24·25	51·07	10·26	8·47	0·35	4·13	82·6
Co. 213	28·72	60·18	10·86	9·45	0·17	1·80	87·0
Co. 223	27·05	57·63	11·18	9·25	0·14	1·51	82·7
Local (Average)	**24·60**	**52·08**	**9·83**	**8·18**	**0·12**	**1·47**	**83·2**
Coimbatore (Average) . . .	**26·67**	**56·29**	**10·77**	**9·06**	**0·22**	**2·40**	**84·1**

TABLE VIII

Period of ripeness for different varieties of cane (Karnal and Rohtak districts)

Year	Varieties of canes					
	Lalri	Suretha	Dhaulu	Co. 205	Co. 213	Co. 223
1927-28 . . .	15/12 to 10/2	3/2 to 21/3	30/12 to 10/4	1/2 to 31/3	15/2 to 1/4	20/2 to 1/4
1928-29 . . .	1/1 to 15/3	15/1 to 15/3	1/1 to 7/2	15/1 to 31/3	15/1 to 15/3	15/1 to 15/3
1929-30 . . .	25/11 to 15/3	25/11 to 31/3	..	10/1 to 31/3	10/1 to 31/3	1/1 to 31/3
1930-31 . . .	23/11 to 1/2	25/1 to 3/4	..	15/12 to 9/4	20/2 to 5/4	20/12 to 15/3
Average period of optimum ripeness	9/12 to 5/3	6/12 to 25/3	31/12 to 21/3	10/1 to 2/4	30/1 to 28/3	14/1 to 23/3

Generally speaking the crushing season may well start with the beginning of December and last till the end of March, *i.e.*, about 120 days.

TABLE IX

Average composition of Katha, Dhaulu and Yuba during period of ripeness (Jullundur and Hoshiarpur districts)

Year	Locality	Weight of stripped cane in tons per acre	Percentage on cane				Glucose ratio	Purity coefficient
			Juice	Total solids	Sucrose	Glucose		
			Katha					
1927-28 . . .	Badala (Bajekhan's)	24·6	61·00	12·14	10·43	0·05	0·4	86·0
	Bhundian .	17·7	62·2	11·82	10·18	0·04	0·4	86·4
	Naugaja (Attar's)	20·3	62·3	11·95	10·22	0·14	1·4	85·5
	Sundarpur .	29·9	62·5	12·25	10·40	0·13	1·2	84·9
	Nagke . .	8·1	62·4	12·49	10·50	0·07	0·7	84·4
	Naugaja (Ishas Singh's)	26·1	61·4	11·91	10·40	0·06	0·6	87·3
	Badala (Jamilkhan)	35·7	60·7	11·72	10·10	0·07	0·7	86·0
	Jandusingha .	21·7	62·5	12·02	10·29	0·11	1·1	86·6
Average for the year	..	**23·0**	**61·9**	**12·04**	**10·32**	**0·08**	**0·8**	**85·7**

1928-29	Kundhalian .	10·7	55·6	10·12	8·40	0·17	2·0	83·0
	Khudda .	15·0	59·5	10·59	8·81	0·30	0·4	83·0
	Rasulpur .	10·3	59·4	10·22	8·61	0·23	3·0	84·0
	Bhundian .	20·3	61·8	10·26	8·49	0·23	3·0	83·0
	Dingrian .	11·7	55·8	10·49	8·76	0·17	2·0	84·0
	Badala Mansurpur	11·2	54·9	10·60	8·84	0·19	2·0	83·0
	Hussainpur .	12·1	55·1	9·53	7·66	0·39	5·0	80·0
	Ramowal (Nakodar)	10·3	57·0	10·06	9·12	0·07	0·7	82·0
	Dhaliwal .	11·0	57·2	9·44	7·66	0·31	4·0	81·0
	Sargondi .	8·9	54·9	10·04	8·62	0·08	1·0	86·0
	Jindowal .	11·5	55·7	10·92	9·36	0·11	1·0	86·0
Average for the year	..	**12·1**	**56·9**	**10·29**	**8·58**	**0·20**	**2·3**	**83·4**
1929-30	Jindowal .	11·5	51·6	9·90	8·20	0·15	2·0	83·0
	Mehli . .	14·7	53·6	10·80	9·30	0·07	1·0	87·0
	Mahl . .	14·9	54·2	10·80	9·00	0·11	1·0	83·0
	Dhaliwal .	16·3	52·8	10·20	8·50	0·16	2·0	83·0
Average for the year	..	**14·4**	**53·1**	**10·40**	**8·80**	**0·12**	**1·4**	**84·6**

TABLE IX—*contd.*

Year	Locality	Weight of stripped cane in tons per acre	Percentage on cane				Glucose ratio	Purity coefficient
			Juice	Total solids	Sucrose	Glucose		
1930-31.	Jabbowal .	12·6	54·1	10·40	8·30	0·13	2·0	80·0
	Sargondi .	12·1	55·7	10·70	8·80	0·34	4·0	82·0
	Dhaliwal .	10·5	54·1	10·00	8·00	0·34	4·0	80·0
	Jullundur .	13·6	58·4	11·00	9·00	0·15	2·0	81·0
	Bhundian .	15·6	58·7	11·30	9·40	0·16	2·0	83·0
	Khudda . .	15·5	57·8	9·90	8·30	0·45	5·0	84·0
	Jhingar Kalan	10·3	56·7	10·10	8·60	0·35	4·0	85·0
Average for the year	..	**12·9**	**56·4**	**10·50**	**8·60**	**0·27**	**3·1**	**81·9**
1931-32	Chuheki .	16·0	60·8	11·40	9·10	0·49	5·4	80·0
	Rehrum .	15·0	56·1	10·70	8·70	0·12	1·4	81·0
	Rasulpur .	18·5	55·5	10·80	9·10	0·18	2·0	84·0
	Jullundur A. S.*	14·9	57·1	10·90	8·20	0·65	7·9	75·0
Average for the year	..	**16·5**	**57·5**	**11·00**	**9·00**	**0·26**	**2·8**	**81·7**

1932-33	Jullundur A. S.*	15·7	57·1	10·90	8·80	0·21	2·4	81·0
Average of six years	..	15·8	57·2	10·86	9·02	0·19	2·1	83·1
Average yield for the last five years	..	14·3	..	..	..	..	..	..
			Dhaulu					
1927-28	Bal . .	24·60	62·60	10·49	9·02	0·06	0·6	86·0
			Yuba					
1927-28	Duleke . .	27·3	67·10	12·22	10·83	0·34	3·1	88·6

* Abnormal sample, figures not taken into calculation.

TABLE X

Average composition of Co. 205 during period of ripeness (Jullundur and Hoshiarpur districts)

Year	Locality	Weight of stripped cane in tons per acre	Percentage on cane				Glucose ratio	Purity coefficient
			Juice	Total solids	Sucrose	Glucose		
1927-28	Kapurpind .	33·8	66·5	11·41	9·01	0·81	8·9	79·0
	Prabhunagar .	27·3	58·8	10·91	9·18	0·31	3·4	84·1
	Bhundian .	21·3	63·8	11·42	9·93	0·25	2·6	86·9
	Bariah . .	29·1	62·7	11·20	9·44	0·35	3·7	83·5
	Dhingrian .	46·5	68·2	11·77	9·86	0·41	4·2	83·8
	Jandusingha .	41·4	57·0	10·85	9·34	0·22	2·3	86·0
	Beaspind .	15·8	59·6	10·99	9·24	0·41	4·4	84·1
	Jullundur (*Chahi*)	13·5	61·3	12·66	9·86	0·10	1·0	78·0
	Jullundur (*Barani*)	7·7	59·0	12·21	9·66	0·14	1·4	79·0
Average for the year	..	**26·3**	**61·9**	**11·49**	**9·50**	**0·33**	**3·5**	**82·7**

1928-29	Nawanpind .	21·1	61·6	9·18	7·14	0·80	11·0	78·0
	Passi Bet .	17·2	62·8	9·86	7·85	0·69	9·0	79·0
	Passi Bet (Ratoon)	15·8	61·3	10·18	8·21	0·86	10·0	81·0
	Bhundian .	17·5	64·0	10·18	8·00	0·49	6·0	79·0
	Dhingrian .	14·8	61·6	9·30	7·70	0·67	9·0	82·0
	Hussainpur .	17·3	61·0	8·42	6·41	1·35	24·0	71·0
	Ramowal (Nakodar)	13·2	60·1	10·64	8·83	0·28	3·0	83·0
	Dhaliwal .	11·2	62·9	10·87	7·67	0·94	12·0	76·0
	Sargondi .	21·1	61·9	10·03	7·68	1·11	15·0	76·0
	Kothran .	18·6	57·6	11·12	9·04	0·51	6·0	81·0
	Jindowal .	18·0	59·5	10·95	9·16	0·36	4·0	84·0
Average for the year	..	16·9	61·3	10·07	7·97	0·73	9·2	79·2
1929-30	Jindowal .	24·4	58·5	11·30	9·60	0·26	3·0	85·0
	Mehli . .	22·8	59·1	11·70	9·80	0·19	2·0	84·0
	Sargondi .	20·7	54·4	11·30	9·60	0·40	4·0	85·0
	Dhaliwal .	19·2	57·5	10·90	8·80	0·43	5·0	81·0
Average for the year	..	21·8	57·4	11·30	9·50	0·32	3·4	84·1

TABLE X—*contd.*

Year	Locality	Weight of stripped cane in tons per acre	Percentage on cane				Glucose ratio	Purity coefficient
			Juice	Total solids	Sucrose	Glucose		
1930-31	Jabbowal .	17·2	61·1	11·40	9·60	0·62	7·0	84·0
	Sargondi .	24·1	62·3	11·80	9·50	0·51	5·0	81·0
	Dhaliwal .	21·2	59·7	11·40	9·10	0·65	7·0	80·0
	Bhundian .	27·9	63·2	11·40	9·40	0·76	8·0	83·0
	Jhingar Kalan	21·0	61·2	9·80	7·50	1·20	16·0	77·0
Average for the year	..	22·3	61·5	11·20	9·00	0·75	8·3	80·3
1931-32	Jabbowal .	22·1	58·5	11·60	9·30	0·74	7·9	80·0
	Chuheki .	24·9	60·6	11·70	9·20	0·91	9·9	79·0
	Khurdpur .	31·1	61·5	11·10	8·70	0·79	9·1	78·0
	Miani Afghana	13·6	59·0	10·80	8·40	0·63	7·5	78·0
	Miani Afghana (Ratoon)	27·7	60·0	11·00	8·90	0·55	6·2	81·0
Average for the year	..	23·9	59·9	11·24	8·90	0·72	8·1	79·2

1932-33	Miani Afghana	17·2	59·1	11·30	9·10	0·68	7·5	81·0
	Khurdpur .	25·8	61·7	11·80	9·50	0·66	6·9	80·0
Average for the year	..	21·5	60·4	11·55	9·30	0·67	7·2	81·0
Average for six years	..	22·1	60·4	11·14	9·03	0·59	6·5	81·1
Average yield for the last five years	..	21·3	..	..	..	..	..	..

TABLE XI

Average composition of Co. 213 during period of ripeness (Jullundur and Hoshiarpur districts)

Year	Locality	Weight of stripped cane in tons per acre	Percentage on cane				Glucose ratio	Purity co-efficient
			Juice	Total solids	Sucrose	Glucose		
1928-29 . . .	Badala Mansurpur	7·7	62·8	10·30	8·79	0·41	5·0	86·0
	Hussainpur (*Pyrilla*)	12·4	64·1	8·72	6·54	1·15	17·0	74·0
	Ramowal .	9·8	61·5	11·07	9·59	0·92	1·0	87·0
	Dhaliwal .	16·2	63·4	10·08	8·31	0·32	4·0	82·0
	Sargondi (*Pyrilla*)	20·7	65·1	8·79	6·64	1·04	16·0	76·0
	Banga . .	21·1	64·8	12·44	10·67	0·17	2·0	85·0
	Karyam . .	17·9	61·0	12·02	10·37	0·09	1·0	87·0
Average for the year	..	**15·1**	**63·3**	**10·49**	**8·40**	**0·59**	**7·0**	**80·1**
1929-30 . . .	Jindowal .	21·5	61·3	11·00	9·50	0·26	3·0	86·0
	Banga . .	35·2	64·1	10·20	8·50	0·26	3·0	83·0
	Khothran .	10·4	55·2	10·20	8·90	0·07	1·0	87·0
	Sargondi .	18·9	59·3	10·60	9·30	0·31	3·0	88·0

	Dhaliwal .	22·6	63·0	11·50	10·20	0·16	2·0	88·0
Average for the year	..	**21·7**	**60·6**	**10·70**	**9·30**	**0·21**	**2·3**	**86·9**
1930-31 . . .	Jabbowal .	20·3	67·5	12·80	11·30	0·28	3·0	89·0
	Sargondi .	20·7	68·5	12·20	10·60	0·34	3·0	87·0
	Dhaliwal .	17·2	63·4	12·50	11·00	0·12	1·0	87·0
	Jullundur A. S.	20·6	63·8	12·50	10·90	0·18	2·0	87·0
	Bhundian .	18·5	69·5	11·70	9·80	0·35	4·0	83·0
Average for the year	..	**19·5**	**67·1**	**12·30**	**10·70**	**0·25**	**2·3**	**87·0**
1931-32 . . .	Jabbowal .	34·6	66·2	12·80	10·80	0·49	4·5	84·0
	Sargondi .	31·1	65·2	12·60	10·80	0·51	4·7	86·0
	Khurdpur .	38·6	66·9	13·00	11·30	0·33	2·9	87·0
	Jullundur A. S.	16·5	67·8	12·50	10·30	0·37	3·7	83·0
Average for the year	..	**30·2**	**66·5**	**12·70**	**10·80**	**0·43**	**4·0**	**85·0**
1932-33 . . .	Mehli . .	17·9	65·3	12·90	11·40	0·09	0·8	89·0
	Nakodar .	19·4	67·7	12·30	10·30	0·17	1·6	85·0
	Khurdpur .	17·2	66·8	12·20	10·80	0·17	1·6	89·0
	ullundur A. S.	34·9	67·1	12·20	10·20	0·27	2·7	84·0
Average for the year	..	**22·4**	**66·7**	**12·40**	**10·70**	**0·18**	**1·7**	**86·3**
Average of five years	..	**21·8**	**64·8**	**11·72**	**9·98**	**0·33**	**3·3**	**85·2**

TABLE XII

Average composition of Co. 223 during period of ripeness (Jullundur and Hoshiarpur districts)

Year	Locality	Weight of stripped cane in tons per acre	Percentage on cane				Glucose ratio	Purity co-efficient
			Juice	Total solids	Sucrose	Glucose		
1927-28 . . .	Jullundur Farm	21·00	67·6	12·22	10·51	0·12	1·2	86·2
	Badala (Bajekhan).	33·04	66·5	11·48	10·35	0·17	1·6	90·0
	Badala (Jamilkhan).	39·56	67·8	11·56	10·40	0·20	1·9	90·0
	Bhundian .	28·27	66·5	11·41	10·08	0·19	1·9	88·3
Average for the year	. .	**30·50**	**67·1**	**11·68**	**10·33**	**0·17**	**1·6**	**88·4**
1928-29 . . .	Nawanpind .	23·00	64·1	9·29	7·88	0·39	5·0	85·0
	Passi Bet .	16·80	65·3	9·34	7·71	0·59	8·0	82·0
	Rasulpur .	18·00	65·8	9·74	8·03	0·59	8·0	82·0
	Bhundian .	22·70	65·8	10·00	7·83	0·41	6·0	78·0
	Badala Mansurpur.	15·40	59·5	9·76	8·51	0·39	5·0	87·0
	Hussainpur .	14·30	63·7	8·28	5·99	1·27	21·0	72·0
	Ramowal (Nakodar).	8·30	60·0	10·50	9·18	0·08	1·0	88·0

	Dhaliwal .	15·40	62·1	9·31	6·89	0·69	10·0	74·0
	Sargondi .	21·20	62·4	8·80	7·05	0·93	13·0	80·0
	Kothran . .	25·10	65·5	9·83	7·86	0·59	8·0	80·0
	Jindowal .	8·60	60·7	10·32	9·23	0·29	3·0	85·0
Average for the year	..	**15·40**	**63·2**	**9·56**	**7·83**	**0·56**	**7·2**	**81·9**
1929-30 . . .	Jindowal .	24·50	59·7	10·40	9·00	0·27	3·0	86·0
	Mehli . .	20·40	57·7	10·30	8·90	0·15	2·0	86·0
	Mehli (*Pyrilla* affected).	21·20	57·7	10·20	8·90	0·17	2·0	87·0
	Sargondi .	19·10	55·0	10·10	9·20	0·24	3·0	91·0
	Dhaliwal .	20·20	61·0	11·40	10·20	0·19	2·0	89·0
Average for the year	..	**21·10**	**58·2**	**10·50**	**9·20**	**0·20**	**2·2**	**87·6**
1930-31 . . .	Jabbowal .	21·20	65·6	11·20	9·50	0·49	5·0	85·0
	Sargondi .	24·30	66·4	11·40	9·80	0·40	4·0	86.0
	Dhaliwal .	17·90	64·6	11·50	10·00	0·34	3·0	87·0
	Jullundur A. S.	24·60	67·2	11·30	9·60	0·62	7·0	85·0
	Bhundian .	22·10	65·6	11·40	9·50	0·54	6·0	84·0
	Rasulpur .	23·10	66·1	10·00	7·90	0·76	10·0	80·0
Average for the year	..	**22·20**	**65·9**	**11·10**	**9·40**	**0·53**	**5·6**	**84·7**

TABLE XII—*contd.*

Year	Locality	Weight of stripped cane in tons per acre	Percentage on cane				Glucose ratio	Purity co-efficient
			Juice	Total solids	Sucrose	Glucose		
1931-32 . . .	Sargondi .	27·00	63·7	11·70	9·80	0·65	6·6	82·0
	Mohanwal .	22·60	64·3	11·70	10·20	0·56	5·5	87·0
	Rasulpur .	30·90	62·1	11·40	9·80	0·51	5·2	85·0
	Jullundur A.S.	22·80	64·0	11·50	8·50	0·51	5·9	81·0
Average for the year	..	**26·83**	**63·4**	**11·60**	**9·93**	**0·57**	**5·7**	**85·6**
1932-33 . . .	Mehli . .	16·10	62·5	11·80	10·40	0·27	2·5	88·0
	Nakodar .	16·20	66·7	11·50	9·60	0·41	4·3	83·0
Average for the year	..	**16·15**	**64·6**	**11·65**	**10·00**	**0·34**	**3·4**	**85·8**
Average for six years	..	**22·03**	**63·7**	**11·02**	**9·45**	**0·40**	**4·3**	**85·8**
Average yield for the last 5 years	..	**20·34**	..	..	..	..	..	..

Table XIII

Average composition of Co. 281 during period of ripeness (Jullundur and Hoshiarpur districts)

Year	Locality	Weight of stripped cane in tons per acre	Percentage on cane				Glucose ratio	Purity co-efficient
			Juice	Total solids	Sucrose	Glucose		
1931-32 . . .	1. Jabbowal .	19·7	66·7	13·0	11·7	0·19	1·6	90·0
	2. Sargondi .	21·6	67·8	13·1	11·5	0·23	2·0	88·0
	3. Mohanwal .	18·0	67·8	13·6	12·2	0·07	0·6	90·0
	4. Khurdpur .	23·8	67·4	13·7	12·2	0·15	1·2	89·0
	5. Rasulpur .	15·6	66·4	13·3	11·6	0·18	1·6	87·0
	*Jullundur A. S.	17·9	70·0	12·0	9·9	0·35	3·5	83·0
Average for the year	..	**19·7**	**67·2**	**13·3**	**11·8**	**0·17**	**1·4**	**89·0**
1932-33 . . .	*Jullundur A. S.	23·2	67·6	13·4	12·1	0·08	0·6	90·0
Average of two years	..	**21·5**	**67·4**	**13·41**	**12·0**	**0·12**	**1·0**	**89·7**

N.B.—Crops at Nos. 1, 2, 3, 4 and 5 in the year 1931-32 were attacked by white ants.
* Crop was badly lodged, the figures heve not been taken into calculation.

TABLE XIV

Average composition of Co. 285 and Co. 290 during period of ripeness (Jullundur and Hoshiarpur districts)

Year	Locality	Weight of stripped cane in tons per acre	Percentage on cane				Glucose ratio	Purity co-efficient
			Juice	Total solids	Sucrose	Glucose		
			Co. 285					
1929-30 . . .	Jullundur Farm	28·3	60·7	11·0	9·0	0·03	0·3	82·0
1930-31 . . .	Jullundur Farm	33·2	65·1	11·2	8·8	0·24	3·0	79·0
	Jullundur Farm (tenants area).	22·4	63·3	11·9	10·0	0·14	1·0	84·0
Average for the year	..	**27·8**	**64·2**	**11·6**	**9·4**	**0·19**	**2·0**	**81·0**
1931-32 . . .	Jabbowal .	31·6	61·7	11·6	9·6	0·41	4·3	83·0
	Sargondi .	36·5	61·7	11·8	9·9	0·37	3·8	84·0
	Chuheki . .	26·2	62·9	12·0	10·2	0·30	3·0	85·0
	Mohanwal .	33·7	62·0	11·8	10·0	0·19	1·9	85·0
	Rasulpur .	35·4	61·2	11·8	9·9	0·18	1·8	84·0
	Miani Afghanan	18·7	64·6	11·4	9·6	0·24	2·5	84·0
Average for the year	..	**30·4**	**62·4**	**11·7**	**9·9**	**0·28**	**2·8**	**84·4**

1932-33 . . .	Jullundur A. S.	28·4	64·2	11·4	8·9	0·35	4·0	78·0
	Mehli . .	29·2	62·6	12·2	10·7	0·22	2·4	87·0
	Chuheki . .	28·2	62·8	12·0	10·4	0·16	1·6	86·0
	Miani Afghanan (Ratoon)	20·2	62·8	11·5	9·6	0·19	2·0	83·0
	Khurdpur .	23·8	62·3	11·2	9·7	0·26	2·7	86·0
	Jullundur A. S.	31·9	63·1	11·4	9·4	0·26	2·8	82·0
Average for the year	..	**26·7**	**62·7**	**11·7**	**10·0**	**0·22**	**2·2**	**85·4**
Average of four years	..	**28·3**	**62·5**	**11·5**	**9·5**	**0·18**	**1·9**	**83·0**

Co. 290

1929-30 . . .	Jullundur A. S.	23·3	64·3	11·2	9·0	0·20	2·0	80·0
1930-31 . . .	Jullundur A. S.	27·4	70·5	10·7	8·4	0·58	7·0	78·0
1931-32 . . .	Jabbowal .	28·7	68·2	13·4	11·7	0·29	2·5	87·0
	Chuheki . .	16·1	68·4	13·1	11·2	0·40	3·6	86·0
	Mohanwal .	31·6	68·2	13·3	11·3	0·42	3·9	85·0
	Khurdpur .	35·9	70·7	13·3	11·2	0·47	4·0	84·0
Average for the year	..	**28·1**	**68·9**	**13·3**	**11·4**	**0·40**	**3·5**	**85·3**
Average of three years	..	**26·3**	**67·9**	**11·7**	**9·6**	**0·39**	**4·1**	**81·7**

TABLE XV

Amount of juice and sucrose, etc., per acre (in tons) and per ton of cane (Jullundur and Hoshiarpur districts)

Variety	Year	Weight per acre				Weight per ton of cane		
		Stripped canes	Juice	Total solids	Sucrose	Juice	Total solids	Sucrose
Katha	1927-28	23·0	14·20	2·76	2·37	0·619	0·120	0·103
	1928-29	12·1	6·88	1·25	1·04	0·569	0·103	0·086
	1929-30	14·4	7·65	1·50	1·27	0·531	0·104	0·088
	1930-31	12·9	7·28	1·35	1·11	0·564	0·105	0·086
	1931-32	16·5	9·49	1·81	1·48	0·575	0·110	0·090
	1932-33	15·7	8·97	1·71	1·38	0·571	0·109	0·088
	Average	**15·8**	**9·01**	**1·71**	**1·43**	**0·572**	**0·109**	**0·090**
Dhaulu	1927-28	24·6	15·40	2·58	2·22	0·626	0·105	0·090
Yuba	1927-28	27·3	18·34	3·34	2·96	0·671	0·122	0.108
Co. 223	1927-28	30·5	20·50	3·57	3·14	0·671	0·117	0·103
	1928-29	15·4	9·73	1·48	1·20	0·632	0·096	0·078
	1929-30	21·1	12·30	2·22	1·94	0·582	0·105	0·092
	1930-31	22·2	14·60	2·46	2·09	0·659	0·111	0·093
	1931-32	26·8	16·99	3·11	2·65	0·634	0·116	0·099
	1932-33	16·2	10·43	1·89	1·61	0·646	0·117	0·100
	Average	**22·0**	**14·04**	**2·47**	**2·08**	**0·637**	**0·112**	**0·095**
Co. 205	1927-28	26·3	16·28	3·02	2·50	0·619	0·115	0·095
	1928-29	16·9	10·36	1·71	1·35	0·613	0·101	0·080
	1929-30	21·8	12·51	2·46	2·07	0·574	0·113	0·095
	1930-31	22·3	13·71	2·50	2·01	0·615	0·112	0·090
	1931-32	23·9	14·30	2·67	2·13	0·599	0·112	0·089
	1932-33	21·5	12·99	2·49	2·00	0·604	0·116	0·093
	Average	**22·1**	**13·34**	**2·46**	**2·00**	**0·604**	**0·111**	**0·090**

Co. 213 . . .	1928-29 . .	15·1	9·56	1·59	1·27	0·633	0·105	0·084
	1929-30 . .	21·7	10·31	2·32	2·02	0·606	0·107	0·093
	1930-31 . .	19·5	13·10	2·40	2·09	0·671	0·123	0·107
	1931-32 . .	30·2	20·08	3·84	3·26	0·665	0·127	0·108
	1932-33 . .	22·4	14·94	2·78	2·40	0·667	0·124	0·107
	Average . .	**21·8**	**14·14**	**2·59**	**2·21**	**0·646**	**0·117**	**0·100**
Co. 285 . . .	1929-30 . .	28·3	17·18	3·12	2·56	0.607	0·110	0·090
	1930-31 . .	27·8	17·84	3·21	2·59	0·642	0·116	0·094
	1931-32 . .	30·4	18·94	3·55	3·00	0·624	0·117	0·099
	1932-33 . .	26·7	16·74	3·16	2·64	0·627	0·117	0·099
	Average . .	**28·3**	**17·68**	**3·25**	**2·70**	**0·625**	**0·115**	**0·96**
Co. 290 . . .	1929-30 . .	23·3	14·98	2·62	2·11	0·643	0·112	0·090
	1930-31 . .	27·4	19·30	2·94	2·30	0·705	0·107	0·084
	1931-32 . .	28·1	19·36	3·24	3·20	0·689	0·133	0·114
	Average . .	**26·3**	**17·88**	**2·90**	**2·54**	**0·679**	**0·118**	**0·096**
Co. 281 . . .	1931-32 . .	19·7	13·27	2·63	2·33	0·672	0·133	0·118
	1932-33 . .	23·2	15·68	3·11	2·81	0·676	0·134	0·121
	Average . .	**21·50**	**14·47**	**2·88**	**2·58**	**0·674**	**0·134**	**0·120**

Table XVI

Composition of juice from different varieties of cane—average of six years (Jullundur and Hoshiarpur districts)

Name of variety of cane	Weight of stripped cane in tons per acre	Percentage on cane				Glucose ratio	Purity co-efficient
		Juice	Total solids	Sucrose	Glucose		
Katha	15·77	57·2	10·86	9·02	0·19	2·1	83·1
Dhaulu	24·60	62·6	10·49	9·02	0·06	0·6	86·0
Yuba	27·30	67·1	12·22	10·83	0·34	3·1	88·6
Co. 223	22·03	63·7	11·02	9·45	0·40	4·3	85·8
Co. 205	22·10	60·4	11·14	9·03	0·59	6·5	81·1
Co. 213	21·78	64·8	11·72	9·98	0·33	3·3	85·2
Co. 285	28·29	62·5	11·49	9·54	0·18	1·9	83·0
Co. 290	26·27	67·9	11·70	9·58	0·39	4·1	81·7
Co. 281	21·47	67·4	13·35	11·97	0·12	1·0	89·7
Local (Katha only)*	15·77	57·2	10·86	9·02	0·19	2·1	83·1
Coimbatore (average)	**23·65**	**64·5**	**11·74**	**9·93**	**0·33**	**3·3**	**84·6**
	Varietal tests at Jullundur Agricultural Station						
Co. 300 (1932-33)	27·2	67·2	12·9	11·3	0·26	2·4	87·0
Co. 301 („)	25·2	67·2	12·8	11·3	0·28	2·6	88·0
Co. 313 („)	23·4	67·1	13·4	11·7	0·25	2·3	88·0
Co. 312 („)	29·8	68·4	12·4	10·8	0·28	2·6	87·0

* Figures for Dhaulu and Yuba, being those from single samples only, have been neglected for calculating average.

Table XVII

Period of optimum ripeness for different varieties of cane (Jullundur and Hoshiarpur districts)

Year	Katha	Dhaulu	Yuba	Co. 223	Co. 205	Co. 213	Co. 285	Co. 290	Co. 281
1927-28 . .	10/1 to 5/2	8/1 to 13/3	8/2 to 28/3	18/2 to 14/3	7/3 to 5/4	..	..	..	..
1928-29 . .	1/12 to 26/2	..	..	1/12 to 15/3	14/12 to 3/4	15/12 to 23/3	..	..	..
1929-30 . .	23/11 to 3/3	..	..	14/2 to 9/4	16/2 to 8/4	8/2 to 7/4	28/2 to 1/4	7/1 to 22/4	..
1930-31 . .	27/11 to 2/3	..	..	20/12 to 15/3	1/2 to 10/4	4/2 to 18/4	2/2 to 9/4	28/1 to 10/4	20/1 to 1/4
1931-32 . .	30/11 to 7/4	..	..	28/1 to 5/3	15/1 to 21/4	8/2 to 22/4	27/12 to 15/4	18/12 to 15/4	16/12 to 6/4
1932-33 . .	4/10 to 30/3	..	..	8/1 to 6/4	..	20/1 to 15/4	20/12 to 22/4	4/1 to 4/4	7/12 to 25/4
Average period of optimum ripeness	21/11 to 8/3	8/1 to 13/3	8/2 to 28/3	15/1 to 21/3	10/2 to 10/4	22/1 to 13/4	20/1 to 12/4	7/1 to 13/4	24/12 to 11/4

Generally speaking the crushing season may start at the beginning of December and last till the middle of April, *i.e.*, about 135 days.

TABLE XVIII

Average composition of Dhaulu and Yuba during period of ripeness (Gurdaspur Circle)

Year	Locality	Weight of stripped cane in tons per acre	Percentage on cane				Glucose ratio	Purity co-efficient
			Juice	Total solids	Sucrose	Glucose		
			Dhaulu					
1927-28 . . .	Kaler Kalan .	9·7	51·9	9·03	7·84	0·36	4·6	86·8
	Sohal . .	10·4	52·0	9·67	8·43	0·22	2·6	87·2
	Tibbar . .	16·2	52·5	9·55	8·14	0·21	2·6	85·2
Average for the year	..	12·1	52·1	9·42	8·14	0·26	3·2	86·4
1928-29 . . .	Chhina . .	4·8	51·2	9·22	8·09	0·21	2·6	87·7
	Sheikhpur .	12·1	55·9	9·75	8·16	0·17	2·1	83·7
Average for the year	..	8·5	53·6	9·49	8·13	0·19	2·3	85·7
1929-30 . . .	Chhina . .	7·4	52·5	8·70	7·60	0·20	2·6	87·3
	Bhopalwala .	15·8	54·5	9·80	8·20	0·30	3·7	83·7
Average for the year	..	11·6	53·5	9·30	7·90	0·25	3·2	84·9
1930-31 . . .	Chhina . .	13·9	47·8	8·96	7·60	0·27	3·6	84·8
	Bhopalwala .	16·9	56·6	10·91	9·08	0·41	4·5	3·2
Average for the year	..	**15·4**	**52·2**	**9·94**	**8·34**	**0·34**	**4·1**	**83·9**

1931-32 . . .	Bhopalwala .	10·8	57·7	9·70	7·80	0·43	5·5	80·4
	Begowal . .	12·8	57·6	10·80	9·00	0·32	3·6	83·3
Average for the year	..	11·8	57·6	10·20	8·40	0·38	4·6	82.3
Average of five years	..	11·9	53·8	9·67	8·18	0.28	3·4	84.6
Average yield for the last four years	..	11·9	..	..	..	..	..	..
				Yuba				
1927-28 . . .	Sohal . .	14·1	62·3	11·03	9·21	0·77	8·4	83.5
1928-29 . . .	Daulatpur .	10·3	64·7	11·78	10·10	0·52	5·2	85.7
Average of two years	..	12.2	63·5	11·40	9·65	0·64	6·6	84.6

TABLE XIX

Average composition of Co. 205 during period of ripeness (Gurdaspur Circle)

Year	Locality	Weight of stripped cane in tons per acre	Percentage on cane				Glucose ratio	Purity co-efficient
			Juice	Total solids	Sucrose	Glucose		
1927-28 . . .	Sangatpur .	21·0	57·2	10·12	7·49	0·46	6·1	74·0
	Nawapind .	16·2	59·0	10·27	8·44	0·77	9·1	82·2
	Dhakki . .	15·0	54·9	9·70	8·23	0·38	4·6	84·8
	Gurdaspur .	18·4	55·5	10·10	8·36	0·51	6·1	82·8
Average for the year	..	**17·7**	**56·7**	**10·05**	**8·13**	**0·53**	**6·5**	**80.9**
1928-29 . . .	Haveli Chobdaran.	13·0	60·0	10·81	9·00	0·84	9·3	83·3
	Pakkhowal .	12·3	60·1	9·92	7·75	0·96	12·4	78·1
	Shahidpur .	10·3	61·1	10·51	8·55	0·79	9·2	81·4
Average for the year	..	**11·9**	**60·4**	**10·41**	**8·43**	**0.86**	**10·2**	**81·0**
1929-30 . . .	Ujela . .	17·5	58·6	9·60	8·20	0·80	9·8	85·4
	Haveli Chobdaran.	17·0	58·7	10·80	8·90	0·90	10·1	82·4
	Sangatpur .	17·8	61·3	11·30	9·60	0·70	7·3	84·9

	Chandowal .	12·5	57·1	10·10	8·40	0·60	7·1	83·2
	Bhopalwala .	20·0	56·7	9·70	7·30	0·80	11·0	75·2
Average for the year	..	17·0	58·5	10·30	8·48	0·76	9·0	82.3
1930-31 .	Haveli Chobdaran.	16·6	59·5	11·17	9·20	0·52	5·7	82·3
	Sialkot . .	31·4	58·7	10·80	9·05	0·25	2·8	83·8
	Bhopalwala .	20·1	56·2	10·90	9·03	0·57	6·3	82·8
Average for the year.	..	22·7	58·1	10·96	9·09	0·45	5·0	82·9
1931-32 . .	Bhopalwala .	20·0	63·3	12·30	10·20	0·65	6·3	83·6
	Gujranwala A. S.	14·8	59·5	10·30	8·40	0·39	4·6	81·6
Average for the year.	..	17·4	61·4	11·30	9·30	0·52	5·6	82·2
Average of the last five years.	..	17·34	59·0	10·60	8·69	0·62	7·1	81.9
Average yield for the last four years.	..	17·25						

TABLE XX

Average composition of Co. 213 during period of ripeness (Gurdaspur Circle)

Year	Locality	Weight of stripped cane in tons per acre	Percentage on cane				Glucose ratio	Purity co-efficient
			Juice	Total solids	Sucrose	Glucose		
1927-28 . . .	Gurdaspur .	18·2	63·1	11·35	9·69	0·44	4·8	85·4
1931-32 . . .	Nawanpind .	15·4	63·9	11·8	10·2	0·42	4·1	86·4
	Chhina . .	20·2	65·4	12·1	10·3	0·64	6·2	85·1
Average for two years	..	**17·8**	**64·6**	**11·95**	**10·25**	**0·53**	**5·2**	**85·8**
1932-33 . . .	Gurdaspur A. S.	17·5	67·0	11·5	10·0	0·45	4·5	87·8
	Nawanpind .	23·1	67·2	12·7	10·8	0·48	4·4	85·0
	Chhina . .	13·7	66·6	11·5	10·0	1·02	10·2	86·9
	Gujranwala A. S.	14·1	66·3	12·0	10·7	0·20	1·9	89·2
	* Rajah Sansi (Red Rot).	18·7	70·8	7·7	5·4	1·39	25·7	70·1
Average for the year.	..	**17·1**	**66·8**	**11·9**	**10·4**	**0·54**	**5·3**	**87·4**
Average of three years	..	**17·7**	**64·9**	**11·73**	**10·11**	**0·50**	**4·9**	**86·2**
Average yield for the last two years	..	**17·5**	..	..	..	..	..	..

* Sample abnormal, figures not taken into calculation when computing averages.

TABLE XXI

Average composition of Co. 223 during period of ripeness (Gurdaspur Circle)

Year	Locality	Weight of stripped cane in tons per acre	PERCENTAGE ON CANE				Glucose ratio	Purity co-efficient
			Juice	Total solids	Sucrose	Glucose		
1927-28 . . .	Dhariwal. .	18·2	60·1	10·33	8·65	0·60	6·9	83·7
	Bham . .	26·0	62·3	10·97	9·41	0·37	3·9	85·8
	Dariwala .	21·0	61·4	10·44	8·72	0·61	7·0	83·5
	Qadian . .	23·0	60·9	10·38	8·71	0·58	6·7	83·9
	Tibbar . .	17·4	62·2	10·70	9·27	0·56	6·0	86·6
	Dhakki . .	15·5	59·5	10·05	8·89	0·36	4·1	88·3
	Gurdaspur .	20·0	62·9	10·11	9·04	0·58	6·4	89·4
Average for the year.	..	20·2	61·3	10·43	8·95	0·52	5·8	85·8
1928-29 . . .	Sheikhupur .	18·2	63·1	10·98	9·40	0·32	3·4	85·6
	Haveli Chobdaran.	21·0	64·9	10·77	9·35	0·45	4·8	86·8
	Daulatpur .	20·3	62·7	10·35	8·65	0·50	5·8	83·6
	Chhina . .	14·7	62·0	9·86	8·18	0·62	7·6	83·0
	Gurdaspur .	22·7	65·6	10·76	9·32	0·59	6·3	86·6

TABLE XXI—*contd.*

Average composition of Co. 223 during period of ripeness (Gurdaspur Circle)—contd.

Year	Locality	Weight of stripped cane in tons per acre	Percentage on cane				Glucose ratio	Purity co-efficient
			Juice	Total solids	Sucrose	Glucose		
Average for the year.	..	**19·4**	**63·7**	**10·54**	**8·98**	**0·50**	**5·6**	**85·2**
1929-30 . . .	Gurdaspur .	22·1	63·4	8·50	7·20	0·80	11·1	84.7
	Chhina . .	10·5	60·4	9·80	8·40	0·80	9·5	85·7
	Nawanpind .	15·3	61·5	8·60	6·00	0·70	11·6	69·8
	Haveli Chobdaran.	17·7	63·1	10·40	8·80	1·0	11·4	84·6
	Adamke . .	20·4	61·2	9·50	8·20	0·50	6·1	86·3
Average for the year.	..	**17·2**	**61·9**	**9·36**	**7·72**	**0·76**	**9·9**	**82·5**
1930-31 . . .	Gurdaspur .	18·6	67·5	11·10	9·70	0·66	6·8	87·4
	Nawanpind .	16·9	63·7	11·25	9·47	0·85	9·0	84·2
	Chhina . .	19·1	64·8	10·63	8·96	0·87	9·7	84·3
	Haveli Chobdaran.	16·8	65·1	11·46	9·93	0·51	5·2	86·7
	Sialkot . .	15·4	64·4	11·36	9·90	0·37	3·7	87·2
	Chandowal .	16·2	65·1	10·62	8·84	0·72	8·2	83·2
	Bhopalwala .	20·3	63·9	10·69	9·19	0·59	6·4	86·0

Average for the year.	..	**17·6**	**64·9**	**11·02**	**9·43**	**0·65**	**6·9**	**85·7**
1931-32 . . .	Gurdaspur A. S.	16·8	59·9	11·00	9·70	0·27	2·8	88·1
	Gurdaspur A. S.	12·3	60·0	10·40	9·20	0·40	4·4	88·5
	Nawanpind .	16·7	61·0	11·00	9·40	0·58	6·2	85·4
	Chhina . .	18·5	63·5	11·80	9·90	0·84	8·5	83·9
	Bhopalwala .	14·4	64·5	11·30	9·51	0·55	5·8	84·0
	Begowal . .	12·2	54·7	9·60	7·82	0·42	5·5	81·2
	Gujranwala A. S.	13·6	65·3	10·90	9·43	0·31	3·3	86·2
	Raja Sansi .	20·3	65·5	10·90	9·24	0·53	5·8	84·4
Average for the year.	..	**15·6**	**61·8**	**10·85**	**9·26**	**0·49**	**5·3**	**85·4**
1932-33 . . .	Gurdaspur A. S.	19·2	65·1	10·70	9·44	0·63	6·7	87·8
	Nawanpind .	22·0	67·1	11·20	9·01	1·03	11·4	80·3
	Chhina . .	14·5	63·9	10·90	9·10	0·80	8·8	83·5
	Chandowal .	14·4	65·7	11·50	9·63	1·00	10·4	83·5
	Sialkot . .	18·5	64·3	11·10	9·21	0·38	4·3	88·3
	Gujranwala A. S.	13·5	64·0	11·00	10·08	0·17	1·7	91·0
	Rajah Sansi .	20·0	63·6	11·70	10·01	0·59	5·9	84·1
	Doburji . .	18·9	62·9	11·60	9·90	0·41	4·1	83·4
Average for the year.	..	**17·6**	**64·6**	**11·20**	**9·55**	**0·62**	**6·7**	**85·1**
Average of six years	..	17·9	63·03	10·57	8·99	0·59	6·57	85·0
Average yield for the last five years.	..	17·5	..	..	..	..	..	..

TABLE XXII

Average composition of Co. 285, Co. 214 and Co. 300 during period of ripeness (Gurdaspur Circle)

Year	Locality	Weight of stripped cane in tons per acre	Percentage on cane				Glucose ratio	Purity co-efficient
			Juice	Total solids	Sucrose	Glucose		
				Co. 285				
1929-30 . . .	Gurdaspur .	22·4	63·6	10·10	8·70	0·50	5·8	86·1
	Chhina . .	12·2	60·7	10·90	9·30	0·40	4·3	85·3
	Nawanpind .	13·3	62·1	10·30	8·70	0·60	6·9	84·5
	Haveli Chobdaran	18·8	62·7	12·50	10·90	0·40	3·7	87·2
	Chandowal .	15·2	59·6	11·10	9·80	0·30	3·1	88·3
Average for the year.	..	**16·4**	**61·8**	**11·00**	**9·48**	**0·44**	**4·8**	**86·2**
1930-31 . . .	Gurdaspur .	24·0	64·1	11·60	10·00	0·50	5·0	86·2
	Nawanpind .	18·4	69·3	11·01	9·37	0·41	4·4	85·1
	Chhina . .	19·6	60·6	10·78	8·98	0·70	7·8	83·3
	Haveli Chobdaran	18·8	62·4	11·77	10·31	0·30	2·9	87·6
	Sialkot . .	19·6	62·2	11·25	9·64	0·35	3·6	85·7
	Chandowal .	23·5	62·1	11·16	9·73	0·49	5·0	87·2

Average for the year.	..	**20·7**	**63·5**	**11·26**	**9·67**	**0·46**	**4·8**	**85·9**
1931-32 . . .	Gujranwala A.S.	14·8	60·9	11·30	9·60	0·20	2·0	85·0
	Gurdaspur A. S.	22·0	59·3	11·20	9·60	0·27	2·8	85·7
	Nawanpind .	22·8	61·9	11·40	9·50	0·48	5·1	83·4
	Rajah Sansi .	26·5	61·9	11·80	9·80	0·31	3·2	83·0
	Chhina . .	21·5	60·1	11·40	9·50	0·58	6·1	83·2
Average for the year.	..	**21·5**	**60·8**	**11·40**	**9·60**	**0·37**	**3·9**	**84·2**
1932-33 . . .	Gurdaspur A. S.	24·2	61·7	10·60	9·20	0·50	5·4	86·8
	Nawanpind .	25·9	61·3	12·40	10·70	0·28	2·6	86·3
	Chhina . .	17·6	63·3	10·90	9·30	0·63	6·9	85·3
	Chandowal .	20·0	62·2	11·70	9·90	0·42	4·3	84·6
	Sialkot A. S. .	23·5	60·9	11·60	10·20	0·23	2·2	88·0
	Gujranwala A.S.	20·0	60·2	11·40	10·20	0·16	1·6	89·5
	Rajah Sansi .	24·8	62·6	10·60	9·00	0·41	4·5	84·9
	Doburji . .	22·0	62·0	11·40	9·70	0·42	4·3	85·1
Average for the year.	..	**22·25**	**61·8**	**11·30**	**9·80**	**0·38**	**3·9**	**86·7**
Average of four years	..	**20·21**	**61·6**	**11·24**	**9·64**	**0·41**	**4·3**	**85·8**
				Co. 214				
1927-28 . . .	Gurdaspur .	10·0	56·4	11·11	9·73	0·18	1·9	87·6
				Co. 300				
1932-33 . . .	Nawanpind .	22·7	64·9	12·0	10·5	0·70	6·8	87·5
	Rajah Sansi * .	19·7	69·2	7·9	5·9	0·74	12·5	85·5

* The figures of analyses have not been taken into consideration as the sample was abnormal.

TABLE XXIII

Average composition of Co. 290 during period of ripeness (Gurdaspur Circle)

Year	Locality	Weight of stripped cane in tons per acre	Percentage on cane				Glucose ratio	Purity co-efficient
			Juice	Total solids	Sucrose	Glucose		
1929-30 . . .	Gurdaspur .	19·1	67·1	9·90	8·50	0·50	5·9	85·9
	Chandowal .	14·2	67·5	12·30	11·20	0·30	2·7	91·0
Average for the year.	..	**16·7**	**67·3**	**11·10**	**9·85**	**0·40**	**4·1**	**88·7**
1930-31 . . .	Gurdaspur .	20·8	70·1	12·70	11·23	0·57	5·1	88·4
	Sialkot . .	11·8	67·0	12·80	11·50	0·38	3·3	89·8
	Chandowal .	19·4	66·0	12·26	10·95	0·45	4·1	89·3
Average for the year.		**17·3**	**67·7**	**12·59**	**11·23**	**0·47**	**4·2**	**89·2**
1931-32 . . .	Gurdaspur A. S.	16·2	65·5	12·00	10·20	0·63	6·2	85·2
	Nawanpind .	20·8	68·6	12·80	11·10	0·24	2·2	86·7
	Rajah Sansi .	23·7	66·2	12·60	10·80	0·23	2·1	85·7
Average for the year.	..	**20·2**	**66·8**	**12·50**	**10·70**	**0·37**	**3·5**	**85·6**
1932-33 . . .	Gurdaspur A. S.	19·0	69·3	12·30	10·90	0·43	3·9	88·6
	Nawanpind .	22·0	69·2	12·74	11·00	0·61	5·5	86·6
	Chandowal .	18·8	67·2	12·81	11·23	0·41	3·7	87·5
	Sialkot . .	24·0	68·4	12·50	11·24	0·24	2·2	89·6
	Gujranwala .	21·2	68·4	12·01	11·02	0·21	1·9	89·0
	Rajah Sansi .	22·7	69·0	11·73	10·01	0·40	4·0	86·3
Average for the year.	..	**21·3**	**68·6**	**12·35**	**10·90**	**0·38**	**3·5**	**88·2**
Average of four years	..	**18·9**	**67·6**	**12·14**	**10·67**	**0·41**	**3·8**	**87·9**

TABLE XXIV

Amount of juice, sucrose, etc., per acre (in tons) and per ton of cane (Gurdaspur Circle)

Variety	Year	Weight per acre				Weight per ton of cane		
		Stripped cane	Juice	Total solids	Sucrose	Juice	Total solids	Sucrose
Dhaulu . . .	1927-28 . .	12.10	6.30	1.14	0.98	0.521	0.094	0.081
	1928-29 . .	8.50	4.56	0.81	0.69	0.536	0.095	0.081
	1929-30 . .	11.60	6.22	1.08	0.92	0.535	0.093	0.079
	1930-31 . .	15.40	8.04	1.45	1.28	0.522	0.094	0.083
	1931-32 . .	11.80	6.80	1.25	1.04	0.576	0.106	0.084
	Average . .	**11.88**	**6.40**	**1.15**	**0.98**	**0.538**	**0.096**	**0.082**
Yuba . . .	1927-28 . .	14.10	8.79	1.57	1.30	0.623	0.110	0.092
	1928-29 . .	10.30	6.66	1.22	1.04	0.647	0.118	0.101
	Average . .	**12.20**	**7.75**	**1.39**	**1.17**	**0.635**	**0.114**	**0.096**
Co. 223 . . .	1927-28 . .	20.16	12.36	2.10	1.81	0.613	0.104	0.090
	1928-29 . .	19.40	12.36	2.04	1.75	0.637	0.105	0.090
	1929-30 . .	17.20	10.65	1.62	1.32	0.619	0.094	0.077
	1930-31 . .	17.60	11.42	1.94	1.65	0.649	0.110	0.094

TABLE XXIV—*contd.*

Amount of juice sucrose, etc., per acre(in tons) and per ton of cane (Gurdaspur Circle)—contd.

Variety	Year	Weight per acre				Weight per ton of cane		
		Stripped cane	Juice	Total solids	Sucrose	Juice	Total solids	Sucrose
	1931-32 . .	15.60	9.64	1.70	1.47	0.618	0.109	0.093
	1932-33 . .	17.60	11.32	1.97	1.67	0.646	0.112	0.095
	Average . .	**17.93**	**11.30**	**1.89**	**1.62**	**0.631**	**0.106**	**0.090**
Co. 205 . . .	1927-28 . .	17.65	10.00	1.78	1.43	0.567	0.101	0.081
	1928-29 . .	11.90	7.19	1.24	1.00	0.604	0.104	0.084
	1929-30 . .	17.00	9.99	1.75	1.45	0.585	0.103	0.085
	1930-31 . .	22.70	13.20	2.50	2.07	0.581	0.110	0.091
	1931-32 . .	17.40	10.72	1.97	1.60	0.614	0.113	0.093
	Average . .	**17.33**	**10.22**	**1.85**	**1.50**	**0.590**	**0.107**	**0.087**
Co. 213 . . .	1927-28 . .	18.20	11.50	2.08	1.77	0.631	0.114	0.097
	1931-32 . .	17.80	11.50	2.14	1.83	0.646	0.120	0.103
	1932-33 . .	17.10	11.42	2.04	1.78	0.668	0.119	0.104
	Average . .	**17.70**	**11.47**	**2.09**	**1.80**	**0.648**	**0.118**	**0.101**

Co. 214 . . .	1927-28 . .	10.00	5.64	1.11	0.97	0.564	0.111	0.097
Co. 285 . . .	1929-30 . .	16.40	10.01	1.80	1.53	0.618	0.110	0.085
	1930-31 . .	20.70	12.80	2.34	2.01	0.618	0.113	0.096
	1931-32 . .	21.50	13.07	2.45	2.06	0.608	0.114	0.097
	1932-33 . .	22.25	13.75	2.51	2.18	0.618	0.113	0.098
	Average . .	**20.21**	**12.46**	**2.28**	**1.97**	**0.616**	**0.113**	**0.097**
Co. 290 . . .	1929-30 . .	16.70	11.20	1.85	1.65	0.673	0.111	0.099
	1930-31 . .	17.30	11.70	2.18	1.93	0.677	0.126	0.112
	1931-32 . .	20.20	13.49	2.53	2.16	0.668	0.125	0.107
	1932-33 . .	21.30	14.61	2.64	2.32	0.686	0.124	0.109
	Average . .	**18.88**	**12.75**	**2.30**	**2.04**	**0.676**	**0.122**	**0.107**
Co. 300 . . .	1932-33 . .	22.70	14.73	2.72	2.38	0.649	0.120	0.105

TABLE XXV

Composition of juice from different varieties of cane—average of six years (Gurdaspur Circle)

Variety of cane	Weight of stripped cane in tons per acre	PERCENTAGE ON CANE				Glucose ratio	Purity co-efficient
		Juice	Total solids	Sucrose	Glucose		
Dhaulu	11.88	53.8	9.67	8.18	0.28	3.4	84.6
Yuba	12.20	63.5	11.40	9.65	0.64	6.6	84.6
Co. 223	17.93	63.0	10.57	8.99	0.59	6.6	85.0
Co. 205	17.34	59.0	10.60	8.69	0.62	7.1	81.9
Co. 213	17.70	64.9	11.73	10.11	0.50	4.9	86.2
Co. 285	20.21	61.6	11.24	9.64	0.41	4.3	85.8
Co. 290	18.98	67.6	12.14	10.67	0.41	3.8	87.9
Co. 214	10.00	56.4	11.11	9.73	0.18	1.9	87.6
Co. 300	22.70	64.9	12.00	10.50	0.70	6.8	87.5
Local (Average)	**12.04**	**58.6**	**10.53**	**8.91**	**0.46**	**5·2**	**84·6**
Coimbatore (Average). . . .	**17.82**	**62.5**	**11.34**	**9.76**	**0.49**	**5.0**	**86.1**

Table XXVI

Period of optimum ripeness for different varieties of cane (Gurdaspur Circle)

Year	Dhaulu	Yuba	Co. 223	Co. 205	Co. 213	Co. 214	Co. 285	Co. 290	Co. 300
1927-28 . .	3/1 to 27/2	15/12 to 30/1	1/2 to 7/4	27/1 to 1/4	15/1 to 15/3	10/1 to 30/2	..	..	..
1928-29 . .	6/12 to 9/2	4/1 to 28/2	1/1 to 16/3	26/12 to 30/3	..	..	..	..	..
1929-30 . .	28/12 to 19/1		4/3 to 30/4	20/1 to 13/4	..	..	10/1 to 15/4	15/1 to 18/4	..
1930-31 . .	21/11 to 24/2	..	15/12 to 6/4	17/3 to 1/4	..	..	5/12 to 9/4	6/12 to 5/4	..
1931-32 . .	27/11 to 20/1	..	1/12 to 20/3	1/2 to 30/3	5/1 to 3/4	..	10/12 to 20/3	20/12 to 20/2	15/12 to 20/2
1932-33 . .	..	..	9/12 to 21/4	..	19/1 to 15/4	..	15/12 to 29/4	15/12 to 21/4	..
Average period of optimum ripeness	**10/12 to 10/2**	**25/12 to 15/2**	**3/1 to 30/3**	**31/1 to 2/4**	**8/1 to 1/4**	**10/1 to 30/2**	**30/12 to 10/4**	**22/12 to 28/3**	**15/12 to 20/2**

Generally speaking the crushing season may start in the second week of December and last till the second week of April, *i.e.*, about 120 days.

TABLE XXVII

Showing the effect of frost on Dhaulu (Chhina, District Gurdaspur)

Date of sampling	Weight of stripped cane per acre in tons	Percentage on cane (Calculated from juice)					Glucose ratio	Purity coefficient	Remarks		
		Juice	Sucrose	Glucose	Total sugars	Total solids					
									Frost on	Rain	On
5th Dec. 1928 .	..	50·9	7·6	0·26	7·9	9·2	3·3	82·7	24-25th Dec. 1928	0.85in.	1st Dec. 1928
									29th Dec. 1928 .	0.74in.	2nd Dec. 1928
19th Dec. 1928 .	..	49·0	7·7	0·15	7·9	8·9	1·9	86·8	6th Jan. 1929 .	0.05in.	29th Dec. 1928
									22nd Jan. 1929 .	0.09in.	26th Jan. 1929
2nd Jan. 1929 .	..	49·6	7·6	0·25	7·9	7·9	3·2	85·5	31st Jan. 1929 (H.F.*)	0.03in.	30th Jan. 1929
									1st-2nd Feb. 1929	0.07in.	9th Feb. 1929
16th Jan. 1929 .	..	54·0	9·1	0·11	9·2	9·2	1·1	89·8	(H. F.*)	0.06in.	13th Feb. 1929
									4.6th Feb. 1929 .		
30th Jan. 1929 .	..	49·4	8·8	0·14	8·9	8·9	1·6	93·2	13th Feb. 1929 .		
									15th Feb. 1929.		
3rd Feb. 1929 .	..	52·9	5·6	0·21	5·8	9·6	2·4	89·5	*H. F.=Heavy frost.		
13th Feb. 1929 .	..	53·0	7·5	0·42	7·9	8·7	5·7	84·7			
3rd Mar. 1929 .	..	50·5	5·8	0·40	6·2	8·1	7·0	71·2			
15th Mar. 1929 .	..	45·4	4·3	0·82	5·1	6·1	18·9	70·9			
27th Mar. 1929 .	..	45·4	3·7	1·27	5·0	5·4	34·5	68·6			
10th April 1929.	..	38·4	2·0	1·73	3·7	4·14	84·9	46·1			
Average for the period of maximum purity	4.8	51·2	8·09	0·21	8·3	9·22	2·53	87·7			

Table XXVIII

Showing the effect of frost on Katha (Khudda, District Hoshiarpur)

Date of sampling	Weight of stripped cane per acre in tons	Percentage on cane (Calculated from juice)					Glucose ratio	Purity coefficient	Remarks		
		Juice	Sucrose	Glucose	Total sugars	Total solids					
									Frost on	Rain	On
23rd Nov. 1928 .	..	57·0	8·4	traces	8·4	10·2	0	82	27th-29th Dec. 1928	0.12in.	28th Nov. 1928
									6-10th Jan. 1929 .	0.53in.	29th Nov. 1928
5th Dec. 1928 .	..	58·5	8·8	,,	8·8	10·3	0	86	21st-23rd Jan. 1929	1.10in.	30th Nov. 1928
									31st Jan. 1929 .	0.71in.	1st Dec. 1928
19th Dec. 1928 .	..	58·6	9·0	,,	9·0	10·8	0	84	1st-2nd Feb. 1929 (H. F.)*	0.16in.	2nd Dec. 1928
										0.21in.	28th Dec. 1928
2nd Jan. 1929 .	..	61·5	9·2	,,	9·2	11·2	0	81	12th Feb. 1929 .	0.56in.	30th Dec. 1928
										0.07in.	24th Jan. 1929
16th Jan. 1929 .	..	60·3	9·2	,,	9·2	10·8	0	85		0.25in.	25th Jan. 1929
										0.10in.	26th Jan. 1929
30th Jan. 1929 .	..	60·8	8·9	,,	8·9	10·7	0	83		0.62in.	29th Jan. 1929
										0.07in.	8th Feb. 1929
1st Feb. 1929 .	..	60·0	8·2	0·23	8·4	10·2	3	80		0.03in.	10th Feb. 1929
14th Feb. 1929 .	..	61·1	8·4	0 43	8·8	10·4	5	80			
28th Feb. 1929 .	..	52·9	6·4	0·42	6·8	8·9	7	72			
Average for the period of maximum purity	15·0	59·5	8·8	0·30	9·11	10·59	0·4	83	*H. F.=Heavy frost.		

Table XXIX

Showing the effect of frost on Katha (Jabbowal, District Hoshiarpur)

Date of sampling	Weight of stripped cane per acre in tons	Percentage on cane (Calculated from juice)					Glucose ratio	Purity coefficient	Remarks
		Juice	Sucrose	Glucose	Total sugars	Total solids			
24th Nov. 1930 .	..	53·5	7·9	0·14	8·0	10·3	1·8	77	Cane was attacked by top borer and smut. Frost on: 8th Dec. 1930 (H. F.*); 12th Dec. 1930 . ; 19th-21st Dec. 1930 ; 22nd-27th Dec. 1930 ; 1st-2nd Jan. 1931 ; 16-17th Jan. 1931 ; 29th Jan. 1931 . ; 31st Jan. 1931 (H.F.*)
8th Dec. 1930 .	..	54·7	8·6	0·11	8·7	10 5	1·3	82	
19th Dec. 1930 .	..	56·6	8·2	0·54	8·7	10·9	6·6	75	
4th Jan. 1931 .	..	59·4	9·0	0·54	9·5	11·0	6·0	82	
18th Jan. 1931 .	..	54·4	6·9	0·97	7·9	10·0	14·0	69	
1st Feb. 1931 .	..	58·6	8·9	0·52	9·4	11·3	5·8	79	
21st Feb. 1931 .	..	57·9	8·7	0·30	9·0	10·8	3·4	80	
6th Mar. 1931 .	..	56·1	9·4	0·44	9·8	11·3	4·8	83	
17th Mar. 1931 .	..	56·8	9·2	0·38	9·6	11·4	4·1	81	
31st Mar. 1931 .	..	53·7	9·2	0·53	9·7	11·3	5·7	81	
19th April 1931 .	.	55·6	8·0	0·43	9·4	11·7	17·9	68	
24th Nov. 1930 to 8th Dec. 1930. (Average during maximum purity period)	12·6	54·1	8·3	0·13	8·4	10·4	1·6	80	

Rain / On

8th Dec. 1930 (H. F.*) 1.40in. 30th Dec. 1930
12th Dec. 1930 . 0.07in. 10th Jan. 1931
19th-21st Dec. 1930 0.19in. 24th Jan. 1931
22nd-27th Dec. 1930 0.32in. 25th Jan. 1931
1st-2nd Jan. 1931 0.11in. 1st Feb. 1931
16-17th Jan. 1931 0.09in. 3rd Feb. 1931
29th Jan. 1931 . 0.34in. 8th Feb. 1931
31st Jan. 1931 (H.F.*) 0.07in. 9th Feb. 1931
0.35in. 18th Feb. 1931
0.29in. 24th Feb. 1931
0.31in. 25th Feb. 1931
0.19in. 3rd Mar. 1931
0.90in. 4th Mar. 1931

*H. F.=Heavy frost.

TABLE XXX

Showing the effect of moderate cold, following heavy frost on Co. 223 (Gurdaspur Agricultural Station)

Date of sampling	Weight of stripped cane per acre in tons	Percentage on cane (Calculated from juice)					Glucose ratio	Purity coefficient	Remarks		
		Juice	Sucrose	Glucose	Total sugars	Total solids					
									Frost on	Rain	On
5th Nov. 1930 .	..	66·7	7·8	1·2	9·0	9·9	15·4	78·8	7-12th Dec. 1930 .	0·05in.	29th Dec. 1930
									20th-21st Dec. 1930	0·12in.	21st Jan. 1931
20th Nov. 1930 .	..	66·4	7·5	1·2	8·7	9·5	16·0	78·9	22nd-27th Dec. 1930	0·40in.	24th Jan. 1931
									1st Jan. 1931 .	0·20in.	25th Jan. 1931
2nd Dec. 1930 .	..	64·3	7·3	1·1	8·4	9·3	15·0	78·5	16th Jan. 1931 .	0·41in.	3rd Feb. 1931
									27th Jan. 1931 .	0·37in.	8th Feb. 1931
18th Dec. 1930 .	..	64·3	8·6	0·8	9·4	10·4	9·3	82·7	29-30th Jan. 1931	0·04in.	9th Feb. 1931
									4-5th Feb. 1931 .	0·74in.	18th Feb. 1931
30th Dec. 1930 .	..	62·4	8·1	0·9	9·0	9·7	11·1	83·5	20th-21st Feb. 1931	0·05in.	19th Feb. 1931
14th Jan. 1931 .	..	66·0	9·6	0·7	10·3	11·1	7·5	86·5		0·78in.	24th Feb. 1931
28th Jan. 1931 .	..	68·9	9·8	0·6	10·4	11·4	6·1	83·9		0·22in.	25th Feb. 1931
11th Feb. 1931 .	..	67·2	9·6	0·7	10·3	11·3	7·3	84·9			
28th Feb. 1931 .	..	66·8	9·1	0·7	9·8	10·6	7·7	85·8			
12th Mar. 1931	..	66·3	9·7	0·4	10·1	11·2	4·1	86·6			
25th Mar. 1931 .	...	67·3	10·5	0·4	10·9	11·6	5·8	90·5			
8th Apl. 1931 .	..	67·4	10·8	0·4	11·2	11·9	3·7	90·7			
22nd Apl. 1931 .	..	63·8	10·7	0·3	11·0	11·6	2·8	92·2			
14th Jan. 1931 to 22nd Apl. 1931 (Average during the maximum purity period.)	29·07	66·71	9·97	0·52	10·49	11·33	5·26	88·0			

TABLE XXXI

Showing the effect of moderate cold following heavy frost on Co. 223 (Gurdaspur Agricultural Station)

Date of sampling	Weight of stripped cane per acre in tons	Percentage on cane (Calculated from juice)					Glucose ratio	Purity coefficient	Remarks
		Juice	Sucrose	Glucose	Total sugars	Total solids			
5th Nov. 1930 .	..	67·6	7·7	1·3	9·0	10·1	16·9	76·2	Manured with ammonium sulphate at 1½ mds. per acre
20th Nov. 1930 .	..	65·6	7·7	1·0	8·7	9·6	13·0	80·2	Frost and rainfall as in Table XXX
2nd Dec. 1930 .	..	64·4	7·0	1·1	8·1	8·9	15·7	78·6	
18th Dec. 1930 .	..	64·9	7·3	1·5	8·8	9·5	20·5	76·8	
30th Dec. 1930 .	..	64·4	7·4	1·1	8·5	9·7	14·9	76·2	
14th Jan. 1931 .	..	66·0	7·4	1·5	8·9	9·8	28·2	75·5	
28th Jan. 1931 .	..	70·4	8·5	1·2	9·7	10·7	14·1	79·4	
11th Feb. 1931 .	..	70·8	8·7	1·2	9·9	11·1	13·8	78·4	
28th Feb. 1931 .	..	67·2	9·5	0·8	10·3	11·2	8·4	84·8	
12th Mar. 1931 .	..	68·5	9·9	0·5	10·4	11·6	5·1	85·3	
25th Mar. 1931	..	67·6	9·8	0·6	10·4	11·3	6·1	86·7	
8th Apl. 1931 .	..	66·8	10·6	0·4	11·0	12·0	3·7	88·3	
22nd Apl. 1931 .	..	64·5	11·2	0·3	11·5	11·9	2·7	94·1	
28th Feb. 1931 to 22nd Apl. 1931 (Average during the maximum purity period)	31·78	66·92	10·20	0·52	10·72	11·6	3·1	87·9	

TABLE XXXII

Showing the delayed ripening of Katha due to frost followed by moderate cold (Chandowal, Sialkot)

Date of sampling	Weight of stripped cane per acre in tons	PERCENTAGE ON CANE (Calculated from juice)					Glucose ratio	Purity coefficient	Remarks		
		Juice	Sucrose	Glucose	Total sugars	Total solids					
6th Dec. 1932 .	..	57·6	9·2	0·52	9·7	11·2	5·7	82·1	Frost on	Rain	On
20th Dec. 1932 .	..	59·0	7·5	0·85	8·4	10·2	11·3	73·5	4th Dec. 1932 .	2·0 in.	24th Dec. 1932
5th Jan. 1933 .	..	53·5	8·7	0·71	9·4	10·5	8·2	82·8	19-11th Dec. 1932 .	0·1 in.	27th Dec. 1932
17th Jan. 1933 .	..	59·6	6·4	1·24	7·6	9·2	19·4	69·8	16-17th Dec. 1932	0·1 in.	30th Dec. 1932
31st Jan. 1933 .	..	62·2	8·2	1·38	9·6	10·7	16·8	76·6	3rd Jan. 1933 .	0·4 in.	18th Jan. 1933
14th Feb. 1933 .	..	56·8	8·7	0·68	9·4	10·1	7·8	86·1	6th Jan. 1933 .	0·1 in.	19th Jan. 1933
5th Mar. 1933 .	..	60·1	6·4	0·86	7·3	10·3	13·4	62·2	8th Jan. 1933 .	0·1 in.	11th Feb. 1933
21st Mar. 1933 .	..	54·1	7·3	0·51	7·8	9·7	7·0	75·2	11-14th Jan. 1933 .	0·2 in.	13th Feb. 1933
4th Apl. 1933 .	..	55·9	10·0	0·47	10·5	11·3	4·7	88·5	15-17th Jan. 1933 .	0·2 in.	25th Feb. 1933
4th Apl. 1933	12·7	55·9	10·0	0·47	10·5	11·3	4·7	88·5	(H. F.)*	0·1 in.	26th Feb. 1933
Average during the period of ripeness									22nd Jan. 1933 .	0·8 in.	8th Mar. 1933
									25th-31st Jan. 1933	0·1 in.	20th Mar. 1933
										0·1 in.	24th Mar. 1933
										1·0 in.	25th Mar. 1933

* H. F.-Heavy frost.

TABLE XXXIII

Showing the effect of frost on Pyrilla *affected Lalri canes (Lehrara, Rohtak)*

Date of sampling	Weight of stripped cane per acre in tons	Percentage on cane (Calculated from juice)					Glucose ratio	Purity coefficient	Remarks
		Juice	Sucrose	Glucose	Total sugars	Total solids			
7th Nov. 1930 .	..	58·5	6·99	0·27	7·26	9·77	3·83	71·5	Frost on Rain On 23rd-25th Dec. 1930 0·13 in. 11th Feb. 1931 1st-4th Jan. 1931 . 0·20 in. 3rd Mar. 1931 0·50 in. 4th Mar. 1931
27th Nov. 1930 .	..	56·9	7·09	0·18	7·27	9·10	2·54	78·0	
4th Dec. 1930 .	..	55·7	6·62	0·31	6·93	8·90	4·68	74·4	
17th Dec. 1930 .	.	58·3	7·53	0·32	7·85	9·32	4·25	80·7	
4th Jan. 1931 .	.	55·7	6·88	0·75	7·63	9·12	10·90	75·4	
21st Jan. 1931 .	..	55·4	5·62	0·78	6·40	9·23	15·60	61·0	
7th Feb. 1931 .	..	56·4	5·75	0·50	6·25	8·80	8·69	65·3	
17th Feb. 1931 .	..	55·6	5·76	0·69	6·45	8·95	12·01	64·3	
5th Mar. 1931 .	..	56·3	6·31	0·70	7·01	9·29	11·10	68·0	
20th Mar. 1931 .	..	51·3	6·78	0·71	7·49	9·79	10·40	69·3	
6th Apl. 1931 .	..	51·7	6·51	0·59	7·10	9·45	9·04	68·9	
(Average during maximum purity period)	17·4	57·4	7·06	0·27	7·33	9·27	3·83	76·1	

Table XXXIV

Showing the effect of frost on Pyrilla *affected Suretha canes (Lehrara Rohtak)*

Date of sampling	Weight of stripped cane per acre in tons	Percentage on cane (Calculated from juice)					Glucose ratio	Purity coefficient	Remarks
		Juice	Sucrose	Glucose	Total sugars	Total solids			
7th Nov. 1930 .	..	65·5	4·93	0·36	5·30	7·45	7·33	66·2	Frost as in Table XXXIII
27th Nov. 1930 .	..	65·1	6·15	0·43	6·58	8·48	7·03	72·5	
4th Dec. 1930 .	..	64·5	4·95	0·64	5·59	7·27	13·00	68·2	
17th Dec. 1930 .	..	64·9	4·40	0·60	5·00	7·05	13·57	62·5	
4th Jan. 1931 .	..	62·3	2·74	1·62	4·36	6·78	59·40	40·5	
21st Jan. 1931 .	..	61·9	2·53	1·81	4·34	7·02	71·70	36·1	
7th Feb. 1931 .	..	61·2	3·18	1·44	4·62	6·49	45·20	49·0	
17th Feb. 1931 .	..	59·8	2·46	2·21	4·67	7·53	90·00	32·7	
5th March 1931	..	55·0	2·78	2·33	5·11	6·91	33·80	40·3	
20th Mar. 1931 .	..	55·5	2·98	1·98	4·96	7·65	46·40	39·0	
6th April 1931	..	58·7	3·53	2·26	5·79	8·39	64·20	42·0	
(Average during maximum purity period.)	22·9	65·0	4·61	0·51	5·12	7·56	10·23	67·3	

TABLE XXXV

Showing the effect of frost on Pyrilla *affected Co. 205 canes, (Lehrara Rohtak)*

Date of sampling	Weight of stripped cane per acre in tons	Percentage on cane (Calculated from juice)					Glucose ratio	Purity coefficient	Remarks
		Juice	Sucrose	Glucose	Total solids	Total solids			
7th Nov. 1930 .	..	67·1	7·31	0·77	8·08	10·30	10·60	71·0	
21st Nov. 1930 .	..	68·5	7·03	0·62	7·65	9·50	8·81	74·0	Frost as in Table XXXIII
4th Dec. 1930 .	..	61·1	7·18	0·60	7·78	9·64	8·34	74·5	
17th Dec. 1930 .	..	66·2	7·70	0·85	8·55	10·12	11·03	76·1	
4th Jan. 1931 .	..	66·5	7·60	1·10	8·70	10·11	14·40	77·0	
21st Jan. 1931 .	..	68·3	7·47	1·38	8·85	9·79	18·40	76·3	
7th Feb. 1931 .	..	67·7	6·56	1·02	7·58	9·07	15·48	72·3	
17th Feb. 1931 .	..	65·6	6·63	1·13	7·76	9·19	17·01	72·2 72·7	
5th Mar. 1931 .	..	65·0	6·27	1·04	7·31	8·62	16·60		
20th Mar. 1931	..	60·4	5·39	1·04	6·43	8·44	19·20	67·6	
6th Apl. 1931 .	..	61·3	6·06	1·23	7·29	8·97	20·40	67·6	
(Average during maximum purity period.(	15·8	64·3	7·30	0·69	7·99	9·75	9·39	74·8	

Table XXXVI

Showing the effect of frost on Co. 213 canes suffering from red rot (Rajah Sansi, Amritsar)

Date of sampling	Weight of stripped cane per acre in tons	Percentage on cane (Calculated from juice)					Glucose ratio	Purity coefficient	Remarks		
		Juice	Sucrose	Glucose	Total sugars	Total solids					
									Frost on	Rain	On
8th Dec. 1932 .	..	68·5	5·0	1·19	6·2	7·4	23·8	67·5	9-10th Dec. 1932 .	0·70 in.	24th Dec. 1932
										0·20 in.	30th Dec. 1932
22nd Dec. 1932 .	..	70·8	5·4	1·39	6·8	7·7	25·7	70·1	16-17th Dec. 1932	0·12 in.	18th Jan. 1933
									4th Jan. 1933 .	0·44 in.	25th Feb. 1933
5th Jan. 1933 .	..	66·8	5·1	1·38	6·5	7·6	27·0	67·1	6th Jan. 1933.		
									8th Jan. 1933.		
19th Jan. 1933 .	..	70·2	5·3	1·34	6·6	7·9	25·3	67·1	10-13th Jan. 1933.		
									14-16th Jan. 1933 (H.F.)*		
2nd Feb. 1933 .	..	68·3	4·9	1·07	6·0	7·4	21·8	66·2	24th-31st Jan. 1933.		
16th Feb. 1933 .	..	69·0	4·8	1·20	6·0	7·7	25·0	62·3	*H. F.-Heavy frost.		
7th Mar. 1933 .	..	68·4	5·9	1·19	7·2	7·7	20·2	76·6	†Calculated.		
6th Apl. 1933 .	..	62·1	3·5	0·80	4·3	5·5	22·8	63·6			
22nd Dec. 1932 Average during the period of ripeness.	18·7†	70·8	5·4	1·39	6·8	7·7	25·7	70·1			

TABLE XXXVII

Showing the effect of frost on Co. 223 canes suffering from red rot (Rajah Sansi, Amritsar)

Date of sampling	Weight of stripped cane per acre in tons	Percentage on cane (Calculated from juice)					Glucose ratio	Purity coefficient	Fibre per cent	Remarks
		Juice	Sucrose	Glucose	Total sugars	Total solids				
8th Dec. 1932 .	..	63·6	10·0	0·59	10·6	11·7	5·9	84·1	..	
22nd Dec. 1932 .	..	69·2	7·8	1·08	8·8	10·2	13·8	76·5	..	Frost and rain as in Table XXXVI
5th Jan. 1933 .	..	67·7	7·1	1·28	8·4	9·7	18·0	73·2	..	
19th Jan. 1933 .		68·9	6·8	1·05	7·9	9·2	15·4	73·9	13·4	
2nd Feb. 1933 .	..	68·5	5·9	1·30	7·5	8·8	22·0	67·0	..	
16th Feb. 1933 .	..	68·2	5·9	1·25	7·2	8·5	21·2	69·4	..	
7th Mar. 1933 .	..	67·1	7·8	0·67	8·5	9·2	8·6	84·8	..	
6th April 1933 .	..	64·1	6·5	0·64	7·1	8·2	9·8	79·2	..	
8th Dec. 1933 (average during the period of ripeness)	20·0*	63·6	10·0	0·59	10·6	11·7	5·9	84·1	13·4	*Calculated

TABLE XXXVIII

Showing the effect of frost on Co. 300 canes suffering from red rot (Rajah Sansi, Amritsar)

Date of sampling	Weight of stripped cane per acre in tons	Percentage on cane (Calculated from juice)					Glucose ratio	Purity coefficient	Fibre per cent	Remarks
		Juice	Sucrose	Glucose	Total sugars	Total solids				
8th Dec. 1932 .	..	66·9	5·7	0·91	6·6	7·9	16·0	72·1	..	
22nd Dec. 1932 .	..	65·8	5·3	0·97	6·3	7·6	18·3	69·8	..	Frost and rain as in Table XXXVI
5th Jan. 1933 .	..	70·2	5·1	1·22	6·3	7·9	23·9	64·5		
19th Jan. 1933 .	..	70·0	5·9	1·21	7·1	8·6	21·0	68·6	10·3	
2nd Feb. 1933 .	..	73·4	4·9	1·44	6·3	7·6	29·1	64·8	..	
16th Feb. 1933 .	..	69·6	5·8	1·07	6·9	8·2	18·4	70·7	..	
7th Mar. 1933 .	..	69·2	5·9	0·74	6·6	6·9	12·5	85·5	..	
6th April 1933 .	..	67·9	4·5	1·00	5·5	7·0	22·2	64·3	..	
7th March 1933 (average during the period of ripeness)	19·7*	69·2	5·9	0·74	6·6	7·9	12·5	85·5	10·3	*Calculated

TABLE XXXIX

Showing the effect of frost in the absence of irrigation water (Khudda, Hoshiarpur)

Date of sampling	Weight of stripped cane per acre in tons	Percentage on cane (Calculated from juice)					Glucose ratio	Purity coefficient	Remarks		
		Juice	Sucrose	Glucose	Total sugars	Total solids					
29th Nov. 1930 .	..	56·9	8·4	0·34	8·7	9·9	4·0	85	Cane attacked by top borer		
11th Dec. 1930 .		58·7	8·1	0·55	8·7	9·9	6·8		Frost on	Rain	on
25th Dec. 1930 .	..	60·2	7·5	0·93	8·4	10·1	12·4	74	8th-12th Dec. 1930 (H. F.)*	0·15 in.	29th Dec. 1930
7th Jan. 1931 .	..	55·2	6·6	0·99	7·6	9·2	15·0	72	19th-21st Dec. 1930	0·11 in.	2nd Feb. 1931
									22nd-27th Dec. 1930 (H. F.)*	0·35 in. 0·07 in.	7th Feb. 1931 8th Feb. 1931
20th Jan. 1931 .	..	56·5	5·8	1·57	7·4	9·0	27·1	64	1st-2nd Jan. 1931	0·72 in.	17th Feb. 1931
									16th-17th Jan. 1931	0·57 in. 0.10 in.	23rd Feb. 1931 1st Mar. 1931.
4th Feb. 1931 .	..	56·1	5·7	1·51	7·2	8·8	26·5	65	29th-30th Jan. 1931.	1.08 in. 0·15 in.	3rd Mar. 1931 4th Mar. 1931
26th Feb. 1931 .	..	51·9	5·6	1·02	6·6	8·0	18·2	70	4th-6th Feb. 1931		
29th Nov. 1930 to 11th Dec. 1930 (average during the maximum purity period)	15·5	57·8	8·3	0·45	8·7	9·9	5·4	84	*H. F. = Heavy frost.		

TABLE XL

Showing the effect of rain alternating with attacks of frost on Katha (Jhabianwala, Jullundur)

Date of sampling	Weight of stripped cane per acre in tons	Percentage on cane (Calculated from juice)					Glucose ratio	Purity coefficient	Remarks		
		Juice	Sucrose	Glucose	Total sugars	Total solids					
25th Nov. 1930 .	..	59·8	9·8	0·06	9·9	12·1	0·6	81	Cane was slightly attacked by top-borer		
6th Dec. 1930 .	..	61·0	10·3	0·09	10·4	12·2	0·9	84			
21st Dec. 1930 .	..	60·0	9·2	0·11	9·3	11·2	1·2	82	Frost on	Rainfall	on
15th Jan. 1931 .	..	55·0	8·4	0·17	8·6	10·5	2·0	80	8th Dec. 1930 .	0·62 in.	29th Dec. 1930
									9th-12th Dec. 1930	0·17 in.	21st Jan. 1931
28th Jan. 1931 .	..	54·5	8·2	0·21	8·4	10·3	2·6	79	19th-27th Dec. 1930	0·61 in.	24th Jan. 1931
									1st-2nd Jan. 1931	0·84 in.	25th Jan. 1931
10th Feb. 1931 .	..	57·4	8·3	0·20	8·5	10·0	2·4	83	16th-17th Jan. 1931	0·12 in.	3rd Feb. 1931
									29th-30th Jan. 1931	0·09 in.	8th Feb. 1931
1st Mar. 1931 .	..	61·7	8·4	0·22	8·6	10·9	2·2	77		0.02 in.	9th Feb. 1931
										0·50 in.	18th Feb. 1931
11th Mar. 1931 .	..	57·7	9·3	0·10	9·4	11·1	1·1	84		0·32 in.	24th Feb. 1931
										0·03 in.	25th Feb. 1931
25th Mar. 1931 .	..	57·1	8·8	0·45	9·3	11·2	5·1	78		0·31 in.	3rd Mar. 1931
										0·19 in.	4th Mar. 1931
10th Apr. 1931 .	..	59·8	7·6	0·61	8·2	10·5	8·0	72		0·25 in.	5th Mar. 1931
										0·01 in.	16th Mar. 1931
26th Apr. 1931 .	..	58·8	5·6	2·18	7·8	10·2	38·9	55			
25th Nov. 1930 to 11th Mar. 1931 (average during maximum purity period)	13·6	58·4	9·0	0·15	9·1	11·0	1·6	81			

TABLE XLI

Showing the effect of frost in the absence of water on Katha (Jhingar Kalan, Jullundur district)

Date of sampling	Weight of stripped cane per acre in tons	Percentage on cane (Calculated from juice)					Glucose ratio	Purity coefficient	Remarks
		Juice	Sucrose	Glucose	Total sugars	Total solids			
29th Nov. 1930 .	..	56·2	8·6	0·32	8·9	10·3	3·7	84	Cane was attacked by Top-borer
11th Dec. 1930 .	..	57·2	8·5	0·38	8·9	9·9	4·5	86	Frost same as mentioned in Table XXXIX
25th Dec. 1930 .	..	58·8	7·9	0·75	8·7	10·0	9·5	79	
7th Jan. 1931 .	..	60·0	7·3	1·21	8·5	9·8	16·6	74	
20th Jan. 1931 .	..	54·3	5·7	1·07	6·8	8·0	18·8	71	
4th Feb. 1931 .	..	57·9	6·3	1·16	7·5	9·2	18·4	68	
26th Feb. 1931 .	..	50·4	4·9	1·15	6·1	7·7	23·4	64	Analyses abandoned, canes killed by frost
29th Nov. 1930 to 11th Dec. 1930 (average during maximum purity period)	10·3	56·7	8·6	0·35	8·9	10·1	4·1	85	

Table XLII

Showing the effect of frost in the absence of water on Co. 205 (Jhingar Kalan, District Jullundur)

Date of sampling	Weight of stripped cane per acre in tons	Percentage on cane (Calculated from juice)					Glucose ratio	Purity coefficient	Remarks
		Juice	Sucrose	Glucose	Total sugars	Total solids			
29th Nov. 1930 .	..	61·2	7·5	1·20	8·7	9·8	16·0	77	
11th Dec. 1930 .	..	62·6	7·5	1·44	8·9	10·1	19·2	74	Frost same as mentioned in Table XXXIX
25th Dec. 1930 .	..	61·4	5·7	2·51	8·2	9·8	44·0	58	
7th Jan. 1931 .	..	63·7	6·6	2·56	9·2	10·2	38·8	65	
20th Jan. 1931 .	..	57·0	4·9	2·58	7·8	8·8	58·1	56	
4th Feb. 1931 .	..	61·2	5·4	2·53	7·9	9·0	46·8	60	
26th Feb. 1931 .	..	55·6	4·6	2·39	7·0	8·3	51·9	55	Analyses abandoned, canes killed by frosts
29th Nov. 1930 (average during the maximum purity period)	21·0	61·2	7·5	1·20	8·7	9·8	16·0	77	

TABLE XLIII

Showing the effect of frost in the absence of water on Co. 205 Ratoon (Jhingar Kalan, Jullundur district)

Date of sampling	Weight of stripped cane per acre in tons	Percentage on cane (Calculated from juice)					Glucose ratio	Purity coefficient	Remarks
		Juice	Sucrose	Glucose	Total sugars	Total solids			
29th Nov. 1930 .	..	58·8	7·2	1·22	8·4	10·4	16·9	69	Cane was attacked by rats and Top-borer
11th Dec. 1930 .	..	59·6	7·6	1·78	9·4	11·1	23·4	68	Frost same as mentioned in Table XXXIX
25th Dec. 1930 .	..	62·4	6·8	1·87	8·7	10·8	27·5	63	
7th Jan. 1931 .	..	59·1	5·2	2·98	8·2	9·9	57·2	53	
20th Jan. 1931 .	..	56·4	5·1	2·87	8·0	9·1	56·2	56	
4th Feb. 1931 .	..	56·4	6·1	2·03	8·1	9·8	33·3	63	
26th Feb. 1931 .	..	55·9	4·8	2·14	6·9	9·3	44·5	51	Analyses abandoned, canes killed by frosts
29th Nov. 1930 . (average during maximum purity period)	12·8	58·8	7·2	1·22	8·4	10·4	16·9	69	

TABLE XLIV

Showing the beneficial effect of irrigation in mitigating injury by frost on Co. 223 (Agricultural Station, Jullundur)

Date of sampling	Weight of stripped cane per acre in tons	Percentage on cane (Calculated from juice)					Glucose ratio	Purity coefficient	Remarks
		Juice	Sucrose	Glucrose	Total sugars	Total solids			
26th Nov. 1930 .	..	67·0	9·5	0·68	10·2	11·3	7·2	84	Cane was attacked by *Pyrilla*, Top-borer, and white ant
4th Dec. 1930 .	..	68·1	8·1	0·96	9·1	10·0	11·8	80	Frost and rain same as mentioned in Table XIX
9th Dec. 1930 .	..	66·8	10·0	0·55	10·6	11·4	5·5	87	
17th Dec. 1930 .	..	69·9	9·0	0·82	9·8	11·0	9·1	82	
14th Jan. 1931 .	..	66·5	8·0	1·17	9·2	10·5	14·6	76	
27th Jan. 1931 .	..	66·5	8·9	0·87	9·8	11·5	9·8	77	
9th Feb. 1931 .	..	65·1	8·4	0·82	9·2	10·6	9·7	79	
25th Feb. 1931 .	..	66·7	8·6	0·89	9·5	10·8	10·3	80	
7th Mar. 1931 .	..	66·7	8·2	0·79	9·0	10·3	9·6	79	
24th Mar. 1931 .	..	65·4	9·2	0·69	9·9	11·1	7·5	83	
9th Apr. 1931 .	..	69·4	9·6	0·63	10·2	11·4	6·5	84	
24th Apr. 1931 .	..	65·7	8·7	1·06	9·8	11·2	12·2	78	
9th Dec. 1930 to 24th Mar. 1931 and 9th Apr. 1931 (Average during maximum purity period)	24·6	67·2	9·6	0·62	10·2	11·3	6·5	85	

Table XLV

Showing the injury to Co. 223 cane by frost in the absence of water (Rasulpur, Hoshiarpur)

Date of sampling	Weight of stripped cane per acre in tons	Percentage on cane (Calculated from juice)					Glucose ratio	Purity coefficient	Remarks
		Juice	Sucrose	Glucose	Total sugars	Total solids			
30th Nov. 1930 .	..	65·3	8·4	0·79	9·2	10·4	9·4	81	Cane was attacked by Top-borer, white-ants and rats
11th Dec. 1930 .	..	66·2	8·1	1·06	9·2	10·6	13·0	76	Frost and rain same as mentioned in Table XXXIX
25th Dec. 1930 .	..	68·3	8·3	1·18	9·5	10·8	14·2	77	
7th Jan. 1931 .	..	65·1	6·8	2·12	8·9	10·4	31·2	65	
20th Jan. 1931 .	..	65·7	7·1	1·39	8·5	9·7	19·6	73	
4th Feb. 1931 .	..	66·4	7·1	1·04	8·1	9·5	14·6	75	
26th Feb. 1931 .	..	66·9	7·4	0·73	8·1	9·5	9·9	78	
8th Mar. 1931 .	..	67·2	6·9	0·87	7·8	8·9	12·6	77	
18th Mar. 1931 .	..	66·8	6·6	0·67	7·3	8·7	10·0	76	
6th April 1931 .	..	64·3	5·9	0·72	6·6	7·8	12·2	75	
20th April 1931 .	..	61·2	5·1	1·27	6·4	7·6	24·9	67	
30th Nov. 1930 . and 26th Feb. 1931 . (average during maximum purity period)	23·1	66·1	7·9	0·76	8·7	10·0	9·7	80	

TABLE XLVI

Showing the protective action of water against frost on Co. 223 (Rasulpur, Hoshiarpur)

Date of sampling	Weight of stripped cane per acre in tons	Percentage on cane (Calculated from juice)					Glucose ratio	Purity coefficient	Remarks
		Juice	Sucrose	Glucose	Total sugars	Total solids			
30th Nov. 1931 .	..	69·1	8·3	1·39	9·7	10·7	16·7	77	Mild attack of *Pyrilla* and white ants
17th Dec. 1931 .	..	67·9	8·2	1·23	9·4	10·5	15·0	79	Frost on — Rain on
6th Jan. 1932 .	..	68·5	9·2	1·35	10·6	11·6	14·6	79	16th-19th Dec. 1931 0·97 in. 9th Jan. 1932.
22nd Jan. 1932 .	..	68·3	8·3	1·42	9·7	11·0	17·1	75	20th-22nd Dec. 1931 1·55 in. 1st Feb. 1932. 26th-28th Dec. 1931 0·25 in. 13th Feb. 1932.
20th Feb. 1932 .	..	65·9	10·5	0·41	10·9	12·0	3·9	87*	29th Dec. 1931 (H.F.*) 0·05 in. 10th Mar. 1932. 31st Dec. 1931 (H·F.*) 0·09 in. 11th Mar. 1932.
4th Mar. 1932 .	..	62·4	9·9	0·66	10·6	11·6	6·7	85	H. F.—Heavy frost
17th Mar. 1932 .	..	57·9	8·9	0·43	9·4	10·6	5·0	84	
20th Feb. 1932 to 17th Mar. 1932 (average during the ripening period)	30·9	62·1	9·8	0·51	10·3	11·4	5·2	85	

TABLE XLVII

Showing the number of cases in which different varieties of sugarcane have been classified according to their resistance towards frost (local varieties)

Serial No.	Variety	Resistance to frost	1928-29				1929-30				1930-31				1931-32				1932-33				Total			
			G	J	K	Total	G	J	K	Total	G	J	K	Total	G	J	K	Total	G	J	K	Total	G	J	K	Total
1	Katha .	Resistant .	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	„ .	Semi-resistant.	...	5	...	5	1	5	...	6	1	5	...	6	1	2	...	3	1	1	...	2	4	18	...	22
	„ .	Non-resistant.	...	6	...	6	...	2	...	2	1	2	...	3	...	2	...	2	...	...	...	...	1	12	...	13
		Total .	...	11	...	11	1	7	...	8	2	7	...	9	1	4	...	5	1	1	...	2	5	30	...	35
2	Dhaulu .	Resistant .	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	„ .	Semi-resistant.	...	...	...	...	1	...	...	1	1	...	...	1	2	...	...	2	...	...	...	...	4	...	...	4
	„ .	Non-resistant.	2	...	1	3	1	...	...	1	1	...	...	1	...	...	...	...	...	...	...	...	4	...	1	5
		Total .	2	...	1	3	2	...	...	2	2	...	...	2	2	...	...	2	...	...	...	...	8	...	1	9
3	Kahu .	Resistant .	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	„ .	Semi-resistant.	...	...	...	...	...	...	...	...	1	...	...	1	...	...	...	...	...	...	...	...	1	...	...	1
	„ .	Non-resistant.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		Total .	...	...	...	...	...	...	...	...	1	...	...	1	...	...	...	...	...	...	...	...	1	...	...	1
4	Yuba .	Resistant .	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	„ .	Semi-resistant.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	„ .	Non-resistant.	1	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	1
		Total .	1	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	1

5	Lalri .	Resistant.	...	...	2	2	...	...	1	1	...	...	1	1	...	...	...	...	...	...	...	...	...	...	4	4
	„ .	Semi-resistant.	...	...	1	1	...	...	3	3	...	...	2	2	...	...	...	...	...	...	...	...	...	...	6	6
	„ .	Non-resistant.	...	...	1	1	...	...	...	...	...	...	1	1	...	...	...	...	...	...	...	...	...	...	2	2
		Total .	...	...	4	4	...	...	4	4	...	...	4	4	...	...	...	...	...	...	...	...	...	...	12	12
6	Suretha	Resistant .	...	...	3	3	...	...	1	1	...	...	1	1	...	...	...	...	...	...	...	...	...	...	5	5
	„ .	Semi-resistant.	...	...	...	...	...	...	2	2	...	...	4	4	...	...	...	...	...	...	...	...	...	...	6	6
	„ .	Non-resistant.	...	...	3	3	...	...	1	1	...	...	1	1	...	...	...	...	...	...	...	...	...	...	5	5
		Total .	...	...	6	6	...	...	4	4	...	...	6	6	...	...	...	...	...	...	...	...	...	...	16	16
	Total .	Resistant .	...	...	5	5	...	...	2	2	...	...	2	2	...	...	...	...	...	...	...	...	...	...	9	9
		Semi-resistant.	...	5	1	6	2	5	5	12	3	5	6	14	3	2	...	5	1	1	...	2	9	18	12	39
		Non-resistant.	3	6	5	14	1	2	1	4	2	2	2	6	...	2	...	2	...	...	...	...	6	12	8	23
		Total .	3	11	11	25	3	7	8	18	5	7	10	22	3	4	...	7	1	1	...	2	15	30	29	74

G = Gurdaspur
J = Jullundur
K = Rohtak-Karnal

TABLE XLVIII

Showing the number of cases in which different varieties of sugarcane have been classified according to their resistance towards frost (Coimbatore varieties)

Serial No.	Variety	Resistance to frost.	1928-29				1929-30				1930-31				1931-32				1932-33				Total			
			G	J	K	Total	G	J	K	Total	G	J	K	Total	G	J	K	Total	G		K	Total	G	J	K	Total
1	Co. 205 .	Resistant .	...	2	3	5	...	...	2	2	1	...	2	3	...	1	...	1	...	...	...	...	1	3	7	11
	,, .	Semi-resistant.	2	6	3	11	4	7	4	15	2	4	1	7	2	4	...	6	...	2	...	2	10	23	8	41
	,, .	Non-resistant.	1	4	1	6	1	...	...	1	...	3	2	5	...	...	...	...	...	...	...	...	2	7	3	12
		Total .	3	12	7	22	5	7	6	18	3	7	5	15	2	5	...	7	...	2	...	2	13	33	18	64
2	Co. 213 .	Resistant .	1	4	2	7	...	2	2	4	...	1	3	4	1	2	...	3	1	4	1	6	3	13	8	24
	,, .	Semi-resistant.	...	1	1	2	...	6	1	7	...	5	3	8	1	2	...	3	3	4	1	8	4	18	6	28
	,, .	Non-resistant.	...	2	2	4	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	1	1	2	2	5
		Total .	1	7	5	13	...	8	3	11	...	6	6	12	2	4	...	6	5	8	2	15	8	33	16	57
3	Co. 223 .	Resistant .	...	2	..	2	...	2	2	4	2	...	1	3	8	1	...	9	...	...	2	2	10	5	5	20
	,, .	Semi-resistant.	2	7	3	12	4	9	2	15	10	6	1	17	4	3	...	7	8	6	...	14	28	31	6	65
	,, .	Non-resistant.	3	2	3	8	1	1	...	2	...	1	...	1	...	...	...	...	...	...	...	...	4	4	3	11
		Total .	5	11	6	22	5	12	4	21	12	7	2	21	12	4	...	16	8	6	2	16	42	40	14	96
4	Co. 270 .	Resistant .	1	...	...	1	1	...	...	1	1	...	...	1	1	...	...	1	...	...	...	...	4	...	...	4
	,, .	Semi-resistant.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	1	1	...	...	1
	,, .	Non-resistant.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		Total .	1	...	...	1	1	...	...	1	1	...	...	1	1	...	...	1	1	...	...	1	5	...	...	5

5	Co. 281 .	Resistant .	1	...	...	1	...	...	...	...	...	1	...	1	...	4	...	4	...	1	...	1	1	6	...	7
	,, .	Semi-resistant.	...	...	...	...	1	...	...	1	...	1	...	1	...	2	...	2	...	...	...	...	1	3	...	4
	,, .	Non-resistant.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		Total .	1	...	...	1	1	...	...	1	...	2	...	2	...	6	...	6	...	1	...	1	2	9	...	11
6	Co. 285	Resistant .	...	...	2	2	2	1	...	3	1	2	2	5	5	3	...	8	1	4	...	5	9	10	4	23
	,, .	Semi-resistant.	1	...	...	1	3	...	1	4	5	...	...	5	...	4	...	4	14	1	...	15	23	5	1	29
	,, .	Non-resistant.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		Total .	1	...	2	3	5	1	1	7	6	2	2	10	5	7	...	12	15	5	...	20	32	15	5	52
7	Co. 290 .	Resistant .	...		...	...	...	1	...	1	2	...	1	3	2	2	...	4	...	...	...	...	4	3	1	8
	,, .	Semi-resistant.	1	...	...	1	2	...	1	3	1	1	...	2	1	3	...	4	6	...	...	6	11	4	1	16
	,, .	Non-resistant.	...	...	2	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	2
		Total .	1	...	2	3	2	1	1	4	3	1	1	5	3	5	...	8	6	...	...	6	15	7	4	26
	Total .	Resistant .	3	8	7	17	3	6	6	15	7	4	9	20	17	13	...	30	3	9	3	15	33	40	25	97
	,, .	Semi-resistant.	6	14	7	27	14	22	9	45	18	17	5	40	8	18	...	26	31	13	1	45	77	84	22	183
	,, .	Non-resistant.	4	8	8	20	2	1	...	3	...	4	2	6	...	...	...	...	1	...	...	1	7	13	10	30
		Total .	13	30	22	64	19	29	15	63	25	25	16	66	25	31	...	56	35	22	4	61	117	137	57	310

G = Gurdaspur J = Jullundur K = Rohtak and Karnal

TABLE XLIX

Effect of Pyrallid borer (Co. 205)

Date of sampling	Description	Percentage on cane				Glucose ratio	Purity coefficient
		Juice	Sucrose	Glucose	Total solids		
15th Dec. 1931 .	Healthy . .	61·9	7·7	0·82	10·9	10·7	75·2
	Diseased . .	59·1	4·9	2·13	9·3	43·5	52·7
21st Jan. 1932 .	Healthy . .	62·1	8·5	0·61	10·9	7·2	78·0
	Diseased . .	62·6	4·9	2·80	10·0	57·1	48·0

TABLE L

Effect of Pyrilla

Yield in tons per acre

Variety	Year	Stripped cane	Total solids	Sucrose	Glucose
Lalri	1929-30*	15·7	1·70	1·38	0·019
	1930-31	16·4	1·61	1·27	0·034
Suretha	1929-30	24·0	2·64	2·13	0·037
	1930-31	19·6	1·97	1·53	0·062
Co. 205	1929-30	22·9	2·50	2·09	0·042
	1930-31	18·6	1·90	1·57	0·074
Co. 213	1929-30	24·3	2·89	2·56	0·019
	1930-31	22·0	2·22	1·84	0·080

*1929-30 crop was practically free from Pyrilla, while in 1930-31 it was severely attacked.

TABLE LI

Data from free and Pyrilla affected neighbouring canes (per cent on cane)

Variety	Juice	Total solid	Sucrose	Glucose	Glucose ratio	Purity coefficient	Remarks
1. Co. 213. .	68·7	9·8	7·4	0·74	10·0	75	Pyrilla-affected
2. „ .	66·8	12·5	10·9	0·18	1·6	87	„ free
3. Co. 223. .	74·2	12·0	10·1	0·50	4·9	84	„ —affected*
4. „ . .	67·2	11·3	9·6	0·62	6·5	85	„ —free*
5. Co. 281. .	69·6	11·5	9·5	0·24	2·6	82	„ —affected
6. „ . .	67·6	13·6	11·9	0·20	1·7	88	„ —free
7. Co.-285. .	65·1	11·2	8·8	0·24	2·7	79	„ —affected
8. „ . .	63·3	11·9	10·0	0·14	1·3	84	„ —free
Mean value .	67·8	10·8	8·6	0·41	4·8	80	„ —affected
	65·9	12·7	10·9	0·17	1·6	86	„ —free

*Omitted from calculation from mean value as this variety was severely attacked by Pyrilla even in the Pyrilla-free fields.

Table LII

Showing that "mosaic" did not affect the composition of the cane

Date of sampling	Variety	Description	Juice	Percentage of cane			Glucose ratio	Purity coefficient
				Total solids	Sucrose	Glucose		
10th Dec. 1929 .	Co. 223 .	Healthy . .	63·1	10·3	9·4	0·6	6·7	91·0
	,, .	Diseased . .	63·6	10·3	9·3	0·6	6·4	90·0
1st Jan. 1931 .	,, .	Healthy . .	65·1	10·7	7·7	1·8	23·3	71·9
	,, .	Diseased . .	65·0	10·9	7·9	1·7	21·5	72·4
2nd Feb. 1931 .	,, .	Healthy . .	68·2	11·6	8·9	1·5	16·8	76·7
	,, .	Diseased . .	69·0	11·7	8·7	1·6	18·4	74·3
12th Jan. 1932 .	,, .	Healthy . .	..	10·1	8·5	0·67	7·9	84·2
	,, .	Diseased . .	..	10·2	8·6	0·68	7·9	84·3

TABLE LIII

Before or soon after the attack of "red rot"

Date of sampling	Variety	Percentage on cane				Glucose ratio	Purity coefficient
		Juice	Total solids	Sucrose	Glucose		
			Before attack				
8th Dec. 1932	Co. 213	68·5	7·4	5·0	1·19	23·8	67·5
	Co.-223	63·6	11·7	10·0	0·59	5·9	84·1
	Co.-285	61·6	10·9	9·3	0·48	5·1	85·3
	Co. 290	68·2	12·4	10·6	0·35	3·3	85·0
	Co. 300	66·9	7·9	5·7	0·91	16·0	72·1
			Two months after the attack				
2nd Feb. 1933	Co. 213	68·3	7·4	4·9	1·07	21·8	66·2
	Co. 223	68·5	8·8	5·9	1·30	22·0	67·0
	Co. 285	63·1	9·8	7·8	0·49	6·3	79·6
	Co. 290	68·0	10·1	7·2	0·77	10·6	72·0
	Co. 300	73·4	7·6	4·9	1·44	29·1	64·8

TABLE LIV

Comparative data on flowering and flowerless canes

Serial No.	Date of sampling	Locality	Average weight per cane in grms.		Juice per cent on cane		In flowers					Flowerless				
			In flowers	Flowerless	In flowers	Flowerless	Sucrose	Glucose	Total solids	Glucose ratio	Purity coefficient	Sucrose	Glucose	Total solids	Glucose ratio	Purity coefficient
							Co. 205.									
1	29th Jan. 1932.	Agri. Farm, Gurdaspur	607 (17)*	508(19)*	58·1	60·8	15·5	0·57	18·4	3·7	84	15·5	0·61	18·6	3·9	83
2	12th Feb. 1932	,, ,, ,,	714 (8)	573(12)	59·7	63·1	15·1	0·50	17·8	3·3	85	13·3	0·75	17·0	5·6	79
3	24th Feb. 1932	,, ,, ,,	766 (5)	448(10)	62·3	59·3	16·9	0·33	19·1	2·0	89	14·7	0·52	17·7	3·6	83
4	1st Mar. 1932 .	,, ,, ,,	745 (9)	519(11)	59·2	62·6	15·6	0·42	18·8	2·7	83	18·6	0·75	16·8	5·5	81
5	23rd Mar. 1932	,, ,, ,,	732 (8)	358(10)	58·9	...	16·9	0·37	19·9	2·2	85	15·6	0·52	18·5	3·3	84
6	22nd Feb. 1932.	Sargondi (Jullundur) .	495(10)	488(10)	56·4	60·0	16·2	0·72	19·1	4·5	85	16·0	1·00	19·1	6·5	82
7	29th Feb. 1932	Kot Kalan (Jullundur)	608(6)	445 (6)	53·7	57·4	16·2	1·06	18·9	6·5	86	14·7	1·41	18·3	9·5	81
8	7th Mar. 1932 .	Sargondi (,,)	413(12)	320(12)	53·3	54·6	19·1	0·80	22·2	4·2	86	17·2	0·92	21·1	5·3	82
9	18th Mar. 1932	Attalgarh (Hoshiarpur)	440(10)	286(10)	57·6	...	...	...	...	...	...	...	...	...	...	Ratoon. ...
10	20th Mar. 1932	Machiwara (Ludhiana)	480(10)	409(10)	57·9	55·7	17·6	0·69	20·7	3·9	83	18·8	0·55	21·2	3·2	81
		Average. .	580	442	57·9	59·2	16·6	0·61	19·5	3·7	85	15·5	0·78	18·5	5·0	83
							Co. 285.									
11	29th Jan. 1931.	Agri. Farm, Gurdaspur	830(17)	562(18)	65·6	65·7	15·9	0·61	18·0	3·8	88	15·2	0·76	17·5	5·0	87
12	19th Feb. 1931	,, ,, ,,	756(20)	647(17)	64·6	66·0	16·3	0·46	18·3	2·8	89	15·5	0·61	17·9	3·9	86
13	13th Mar. 1931	,, ,, ,,	725(20)	472(20)	64·4	64·9	16·6	0·31	19·1	1·9	87	16·3	0·31	18·6	1·9	88
14	23rd Feb. 1932	Jabbowal (Jullundur)	880 (9)	638 (8)	59·5	61·8	17·2	0·40	19·1	3·4	89	16·0	0·33	18·0	2·1	89
15	9th Mar. 1932 .	,, ,, .	944 (9)	750(9)	63·5	63·3	17·7	0·26	20·0	1·4	88	17·3	0·35	19·8	2·0	88
16	18th Mar. 1932	Attalgarh (Hoshiarpur)	875 (8)	769 (8)	57·8	56·5	17·1	0·18	19·8	1·1	87	17·0	0·19	19·5	1·1	87
17	20th Mar. 1932	Lalaudi (Ludhiana) .	753(10)	689(10)	55·9	57·1	18·0	0·31	21·0	1·7	86	18·2	0·26	21·1	1·4	87
		Average .	803	616	61·6	62·2	17·0	0·36	19·3	2·1	88	16·5	0·40	18·9	2·4	87

Figures within brackets indicate the number of individual canes weighed to get the average weight of one cane.

TABLE LV

Rainfall in inches during five years in the Gurdaspur and Jullundur districts during the sugarcane seasons 1927-28 to 1931-32

	March	April	May	June	July	August	September	October	November	December	January	February	Total
1927-28 G	1·35	0·25	2·33	0·81	10·08	6·34	0·77	...	0·05	0·67	2·67	1·19	26·51
„ J	0·72	0·10	0·57	1·90	11·14	3·93	0·18	...	0·10	1·22	2·29	2·64	24·79
1928-29 G	0·39	0·12	0·18	0·90	4·07	9·71	3·50	0·18	2·85	2·59	0·74	0·30	26·63
„ J	0·10	0·28	0·20	1·83	1·63	3·10	2·17	...	0·76	1·32	0·50	0·10	11·99
1929-30 G	..	..	0·22	3·04	10·50	4·67	0·87	3·68	..	5·93	1·98	1·04	31·93
„ J	..	0·41	..	2·47	9·64	3·45	1·60	1·11	..	2·19	0·90	1·00	22·77
1930-31 G	1·08	1·47	0·05	3·39	15·45	4·95	2·53	0·08	..	0·05	0·72	2·53	32·30
„ J	0·31	0·40	..	2·42	10·31	3·34	6·09	..	..	0·54	1·52	0·98	25·97
1931-32 G	0·96	0·45	1·21	0·60	4·42	14·6	1·08	0·63	..	..	1·52	1·77	27·14
„ J	0·75	0·28	1·50	0·16	6·21	13·4	0·38	1·16	..	0·02	0·44	0·70	25·00
						1927	1928	1929	1930	1931			
Total for September, October, November and December—G						1·49	9·12	10·48	2·66	1·71*			
J						1·50	4·25	4·90	6·63	1·56*			

NOTE.—'G' stands for Gurdaspur and 'J' for Jullundur.

* 2·66 inches of rain at Gurdaspur and 1·08 in. at Jullundur, recorded on 1st September 1931, are not included as they relate to rain received on 31st August 1931

TABLE LVI

Yields in maunds of gur *per acre from plant and its ratoon crops*

Year	Co. 213	Co. 223	Remarks
1928-29 . . .	59·58	56·80	Plant crop
1929-30 . . .	44·80	52·40	First ratoon
1930-31 . . .	45·75	53·85	Second ratoon
1931-32 . . .	42·40	52·10	Third ratoon
1932-33 . . .	36·00	53·90	Fourth ratoon

TABLE LVII

Comparative data for plant and ratoon crop

Variety	Year	Weight in tons per acre				Percentage on stripped cane				Purity coefficient.
		Stripped cane	Sucrose	Glucose	Total solids	Juice	Sucrose	Glucose	Fibre	
Co. 205 .	1931-32 (Plant crop) . .	13·6	1·22	0·078	1·66	59·0	9·0	0·57	..	78
„	1932-33 (Ratoon crop) . .	17·2	1·56	0·117	1·94	59·1	9·1	0·68	20·8	81
Co. 285 .	1931-32 (Plant crop) . .	18·7	1·80	0·045	2·13	59·6	9·6	0·24	..	84
„ .	1932-33 (Ratoon crop) . .	20·2	1·94	0·038	2·32	62·8	9·6	0·19	16·1	83

TABLE LVIII

Fibre percentage on cane

	Jullundur	Gurdaspur
Katha	18·1	21·7
Co. 205	18·5	..
Co. 213	14·5	12·7
Co. 223	11·8	14·5
Co. 270	..	17·2
Co. 281	13·9	17·2
Co. 285	16·5	17·7
Co. 290	12·2	12·0
Co. 300	14·5	12·2
Co. 301	14·0	..
Co. 312	13·0	..
Co. 313	15·0	..

TABLE LIX

Showing results from water-withholding experiments (1932-33)

Locality	Weight of stripped cane in tons per acre	Percentage on cane				Glucose ratio	Purity coefficient
		Juice	Total solids	Sucrose	Glucose		
		Normal watering					
		Co. 213					
Jullundur Agricultural Station	20·7	67·4	12·9	11·3	0·28	2·6	88
Jallowal	18·0	65·6	12·3	10·8	0·33	3·1	88
Baiyanpur (Sonepat)	27·3	68·8	11·7	9·9	0·46	4·7	85
Average	22·0	67·3	12·3	10·7	0·36		
		Co. 223					
Jullundur Agricultural Station	24·2	65·9	11·6	10·1	0·41	4·1	87
Jallowal	15·6	63·7	11·7	10·3	0·55	5·3	88
Agricultural Farm, Hansi	23·2	63·7	11·6	10·3	0·38	3·8	88
Average	21·0	64·4	11·6	10·2	0·45		
		Water withheld from 1st October onwards					
		Co. 213					
Jullundur Agricultural Station	20·3	67·7	13·0	11·4	0·39	3·6	87
Jallowal	14·2	65·5	12·2	10·7	0·40	3·8	88
Baiyanpur (Sonepat)	23·5	69·8	12·1	10·1	0·52	5·1	83
Average	19·3	67·7	12·4	10·73	0·44		
		Co. 223					
Jullundur Agricultural Station	18·9	66·4	11·7	10·1	0·44	4·4	87
Jallowal	14·8	63·3	11·7	10·3	0·54	5·3	88
Agricultural Farm, Hansi	17·7	64·4	12·4	11·0	0·40	3·6	89
Average	17·1	64·7	11·9	10·5	0·46		

TABLE LX

Showing effect of artificial manures on Co. 223 plant crop

Manure applied	Weight in tons per acre				Percentage on cane			
	Stripped cane	Sucrose	Glucose	Total solids	Juice	Sucrose	Glucose	Total solids
Potassium nitrate . .	32·23	3·36	0·157	3·76	67·4	10·4	0·49	11·7
Superphosphate . .	29·23	2·97	0·141	3·38	67·7	10·2	0·49	11·6
Ammonium sulphate . .	31·78	3·24	0·165	3·69	66·9	10·2	0·52	11·6
Ammonium phosphate .	28·97	2·97	0·152	3·33	67·4	10·3	0·52	11·5
Control	29·07	2·90	0·153	3·29	66·7	10·0	0·52	11·4

TABLE LXI

Showing effect of artificial manures on Co. 285 plant crop

Manure applied	Weight in tons per acre				Percentage on cane			
	Stripped cane	Sucrose	Glucose	Total solids	Juice	Sucrose	Glucose	Total solids
Potassium nitrate . .	27·4	2·68	0·093	3·04	61·2	9·8	0·34	11·1
Superphosphate . .	24·0	2·40	0·067	2·74	61·2	10·0	0·28	11·4
Ammonium sulphate . .	28·4	2·90	0·071	3·27	60·9	10·2	0·25	11·5
Ammonium phosphate .	27·2	2·77	0·075	3·10	60·5	10·2	0·27	11·4
Control	21·4	2·14	0·051	2·33	59·2	10·0	0·24	10·9

TABLE LXII

Yield of stripped cane in tons per acre (1927-28 to 1932-33)

Year	Circle	Lalri	Suretha	Dhaulu	Katha	Co. 205	Co. 213	Co. 223	Co. 270	Co. 281	Co. 285	Co. 290	Co. 300	Co. 301	Co. 312	Co. 313	Average of local varieties	Average of Co. varieties
1927-28	Gurdaspur	...	...	12·1	...	17·6	18·2	20·2	...	...	...	...	...	...	...	...	12·1	18·7
,,	Jullundur	...	...	24·6	25·1	28·6	...	30·5	...	...	...	...	...	...	...	...	24·8	29·5
,,	Rohtak-Karnal	29·0	42·8	26·0	...	28·4	35·3	26·9	...	...	...	...	...	...	...	...	32·6	30·2
																	23·2	26·2
1928-29	Gurdaspur	...	...	8·5	...	13·0	22·5	20·3	26·9	20·4	30·0	27·0	...	...	...	...	8·5	22·6
,,	Jullundur	...	...	...	12·2	16·8	13·3	17·9	...	...	...	...	...	...	...	...	12·2	16·0
,,	Rohtak-Karnal	20·7	24·8	25·2	...	26·9	28·5	30·6	...	...	...	...	...	...	...	...	23·6	28·7
																	14·8	22·4
1929-30	Gurdaspur	...	...	11·6	11·2	16·9	...	19·1	21·4	12·4	15·8	16·7	...	...	...	...	11·4	17·0
,,	Jullundur	...	...	...	14·4	23·8	25·9	22·1	...	...	28·3	23·3	...	...	...	...	14·4	24·7
,,	Rohtak-Karnal	15·7	24·0	...	...	22·9	24·3	23·7	...	...	...	...	...	...	...	...	19·9	23·6
																	15·2	21·8
1930-31	Gurdaspur	...	...	15·4	13·7	22·7	...	17·6	20·3	...	20·0	17·3	...	...	...	...	14·5	19·6
,,	Jullundur	...	...	...	12·9	20·2	21·2	23·3	...	22·8	27·8	27·4	...	...	...	...	12·9	20·4
,,	Rohtak-Karnal	16·4	19·6	...	...	18·6	22·0	...	...	..	...	...	...	...	...	...	18·0	20·3
																	15·1	20·1
1931-32	Gurdaspur	...	...	...	9·0	17·4	17·8	16·0	13·6	...	21·5	20·3	...	...	...	...	9·0	17·2
,,	Jullundur	...	...	...	16·1	23·9	30·2	25·8	...	19·4	30·1	27·3	...	...	...	...	16·1	26·1
																	12·5	21·6
1932-33	Gurdaspur	...	...	...	12·7	...	17·1	17·6	21·5	...	22·2	21·3	22·7	...	...	...	12·7	20·4
,,	Jullundur	...	...	...	15·7	21·5	21·4	18·0	...	23·2	26·7	24·4	27·2	25·2	29·8	23·3	15·7	24·1
																	14·2	22·2
Average	Gurdaspur	...	...	11·9	11·6	17·5	18·9	18·4	17·3	16·4	21·9	20·5	22·7	...	...	...		
	Jullundur	...	...	...	16·1	22·5	28·0	22·8	...	21·8	28·2	25·6	27·2	25·2	29·8	23·3		
	Rohtak-Karnal	20·5	27·8	25·6	...	24·2	27·5	27·1	...	...	...	...	...	...	...	...		

Table LXIII

Amounts of sucrose in tons per acre (1927-28 to 1932-33).

Year	Circle	Lalri	Suretha	Dhaulu	Katha	Co. 205	Co. 213	Co. 223	Co. 270	Co. 281	Co. 285	Co. 290	Co. 300	Co. 301	Co. 312	Co. 313	Average local varieties	Average coimbatore varieties
1927-28	Gurdaspur	...	...	0·98	...	1·49	1·77	1·86	...	...	...	...	...	...	...	...	0·98	1·71
,,	Jullundur	...	...	2·22	2·59	2·71	...	3·15	...	...	...	...	...	...	...	...	2·41	2·93
,,	Rohtak-Karnal	2·25	3·84	2·36	...	2·45	3·72	2·79	...	...	...	...	...	...	...	...	2·82	2·99
																	2·07	2·54
1928-29	Gurdaspur	...	...	0·68	...	1·01	2·11	1·76	2·78	2·31	2·76	2·89	...	...	...	...	0·68	2·23
,,	Jullundur	...	...	...	1·04	1·38	1·12	1·40	...	...	...	...	...	...	...	...	1·04	1·30
,,	Rohtak-Karnal	1·53	2·00	1·82	...	2·10	2·33	2·23	...	...	...	...	...	...	...	...	1·17	1·92
																	1·17	1·92
1929-30	Gurdaspur	...	...	0·93	1·02	1·40	...	1·44	1·89	1·19	1·52	1·61	...	...	...	...	0·98	1·51
,,	Jullundur	...	...	...	1·24	2·28	2·88	2·10	...	...	2·56	2·11	...	...	...	...	1·24	2·39
,,	Rohtak-Karnal	1·38	2·13	...	...	2·09	2·56	2·35	...	...	...	...	...	...	...	..	1·76	2·33
																	1·33	2·08
1930-31	Gurdaspur	...	...	1·29	1·25	2·15	...	1·66	2·45	...	2·02	2·03	...	...	...	...	1·27	2·06
,,	Jullundur	...	...	...	1·10	1·82	2·12	2·21	...	2·41	2·59	2·31	...	...	...	...	1·10	2·24
,,	Rohtak-Karnal	1·27	1·53	...	...	1·57	1·94	...	...	...	...	...	...	...	...	...	1·40	1·71
																	1·26	2·00
1931-32	Gurdaspur	...	...	1·08	0·83	1·64	1·82	1·50	1·22	...	2·07	2·17	...	...	...	...	0·96	1·74
,,	Jullundur	...	...	...	1·42	2·15	3·29	2·48	...	2·23	2·93	3·01	...	...	...	...	1·42	2·68
																	1·19	2·21
1932-33	Gurdaspur	...	...	...	1·27	...	1·79	1·69	2·19	...	2·18	2·31	2·38	...	...	...	1·27	2·09
,,	Jullundur	...	...	...	1·38	2·00	2·29	1·82	...	2·81	2·66	2·98	3·07	2·85	3·22	2·74	1·38	2·64
																	1·33	2·37
Average	Gurdaspur	...	...	0·93	1·09	1·52	1·87	1·65	2·11	1·75	2·11	2·20	2·38	...	...	...		
	Jullundur	...	...	2·22	1·46	2·06	2·34	2·19	...	2·48	2·69	2·60	3·07	2·85	3·22	2·74		
	Rohtak-Karnal	1·61	2·38	2·36	...	2·05	2·61	2·46	...	...	...	...	...	...	...	...		

TABLE LXIV

Average outturn in tons per acre (1927-28 to 1932-33)

Name of circle	Stripped cane		Sucrose	
	Local	Coimbatore	Local	Coimbatore
Gurdaspur	11·2	19·6	1·04	1·95
Jullundur	17·3	24·1	1·57	2·62
*Rohtak-Karnal	24·60	26·67	1·83	2·35

*From year 1927-28 to 1930-31.

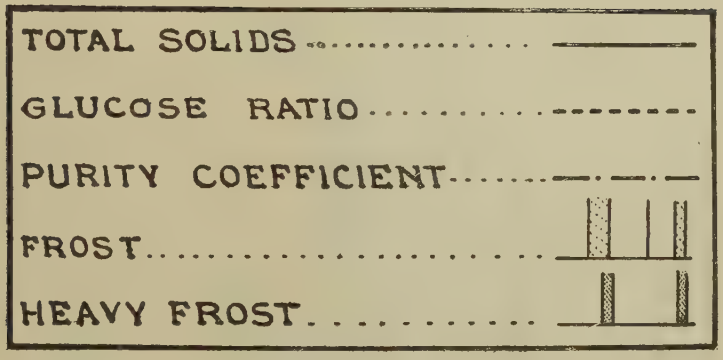
Table LXV

Area (in acres) under sugarcane in the Punjab

District	1927-28	1928-29	1929-30	1930-31	1931-32	1932-33	Average of the six years
Hissar . . .	1,208	451	211	568	1,062	1,705	866
Rohtak . . .	41,369	29,034	15,273	35,422	27,713	37,889	31,117
Gurgaon . . .	10,636	6,455	3,889	9,505	11,710	12,230	9,071
Karnal . . .	33,932	21,287	21,856	29,839	25,611	32,180	27,451
Amballa . . .	17,817	16,861	12,460	13,463	17,040	24,587	17,038
Simla . . .	1	..	..	..	..	..	..
Kangra . . .	5,561	5,094	2,293	3,119	4,259	4,762	4,181
Hoshiarpur . .	28,818	25,551	14,609	21,076	26,467	34,053	25,096
Jullundur . . .	32,240	26,194	19,959	27,644	31,638	37,095	29,128
Ludhiana . . .	15,449	11,676	9,578	11,382	14,125	18,870	13,513
Ferozepur . . .	4,823	3,096	1,906	3,993	5,422	10,634	4,979
Lahore . . .	19,190	13,786	7,590	14,819	25,360	28,540	18,214
Amritsar . . .	32,405	24,002	17,468	22,065	25,758	32,519	25,703
Gurdaspur . . .	61,624	54,418	38,131	49,613	58,397	69,584	55,295
Sialkot . . .	40,874	36,038	30,987	34,795	32,820	37,628	35,524

District	1927-28	1928-29	1929-30	1930-31	1931-32	1932-33	Average of the six years
Gujranwala . .	25,244	25,124	25,092	23,248	21,806	25,430	24,324
Sheikhupura . .	20,171	16,739	17,068	19,804	19,760	22,223	19,294
Gujrat . . .	12,904	12,140	10,798	9,303	8,964	13,376	11,248
Shahpur . . .	8,816	8,144	8,472	8,559	8,512	9,547	8,675
Jhelum . . .	217	175	120	128	190	252	180
Rawalpindi. . .	79	87	63	62	73	86	74
Attack . . .	781	674	665	777	820	834	759
Mianwali . . .	76	80	42	14	29	67	51
Montgomery . .	15,000	10,007	6,176	13,138	19,801	19,775	13,983
Lyallpur . . .	51,445	39,082	30,946	55,762	63,551	55,475	49,377
Jhang . . .	2,847	2,683	3,043	4,300	4,704	4,482	3,677
Multan . . .	8,712	6,742	4,259	8,928	12,953	15,594	9,531
Muzaffargarh . .	6,319	4,880	3,548	4,001	5,983	8,567	5,550
Dera Ghazi Khan .	66	104	104	102	127	168	112
Total .	498,624	400,904	306,696	425,729	474,555	558,152	447,011

References to Figs. 1—16



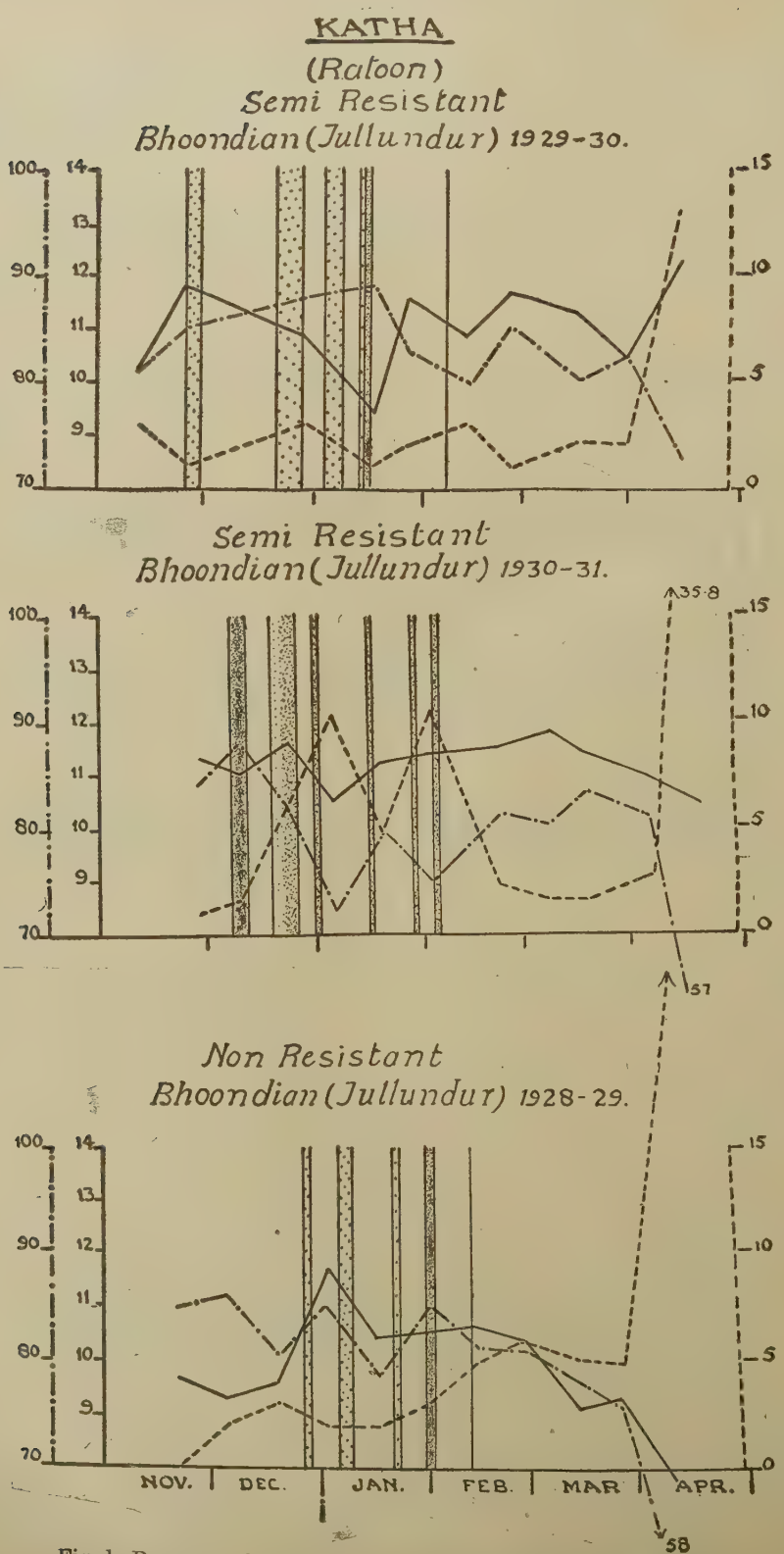


Fig. 1. Response of Katha to frost as a semi and non-resistant can

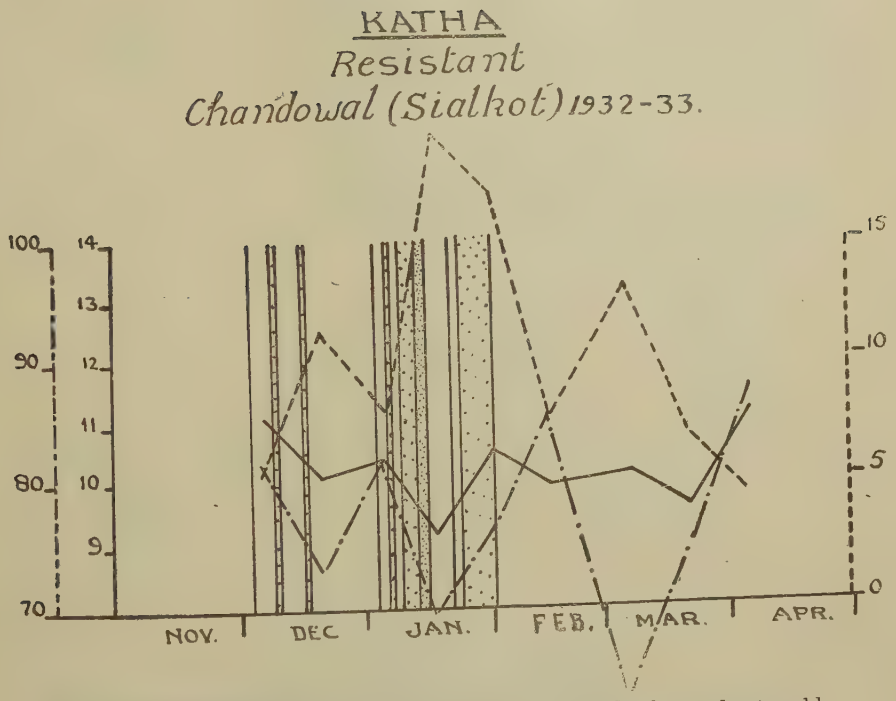


Fig. 2. Delayed maturity of Katha due to frost succeeded by moderate cold

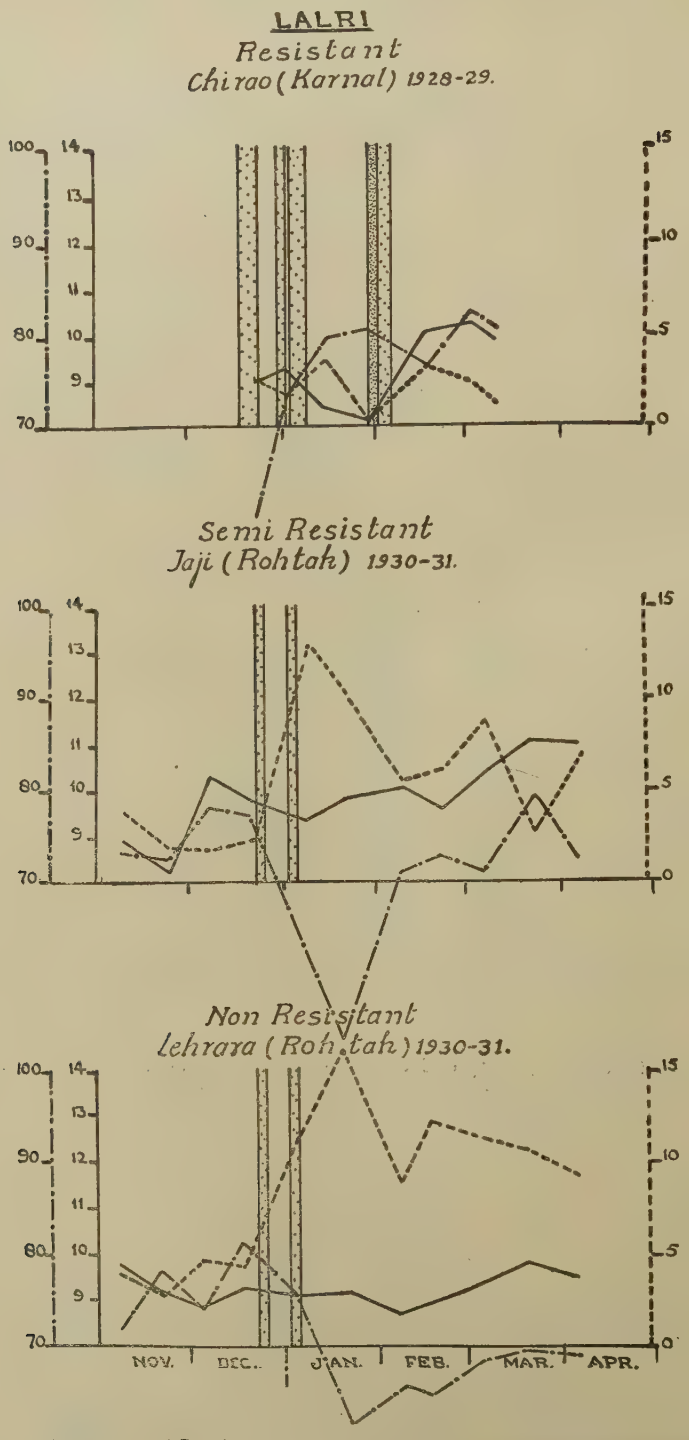


Fig. 3. Response of Lalri to frost as a resistant, semi and non-resistant cane

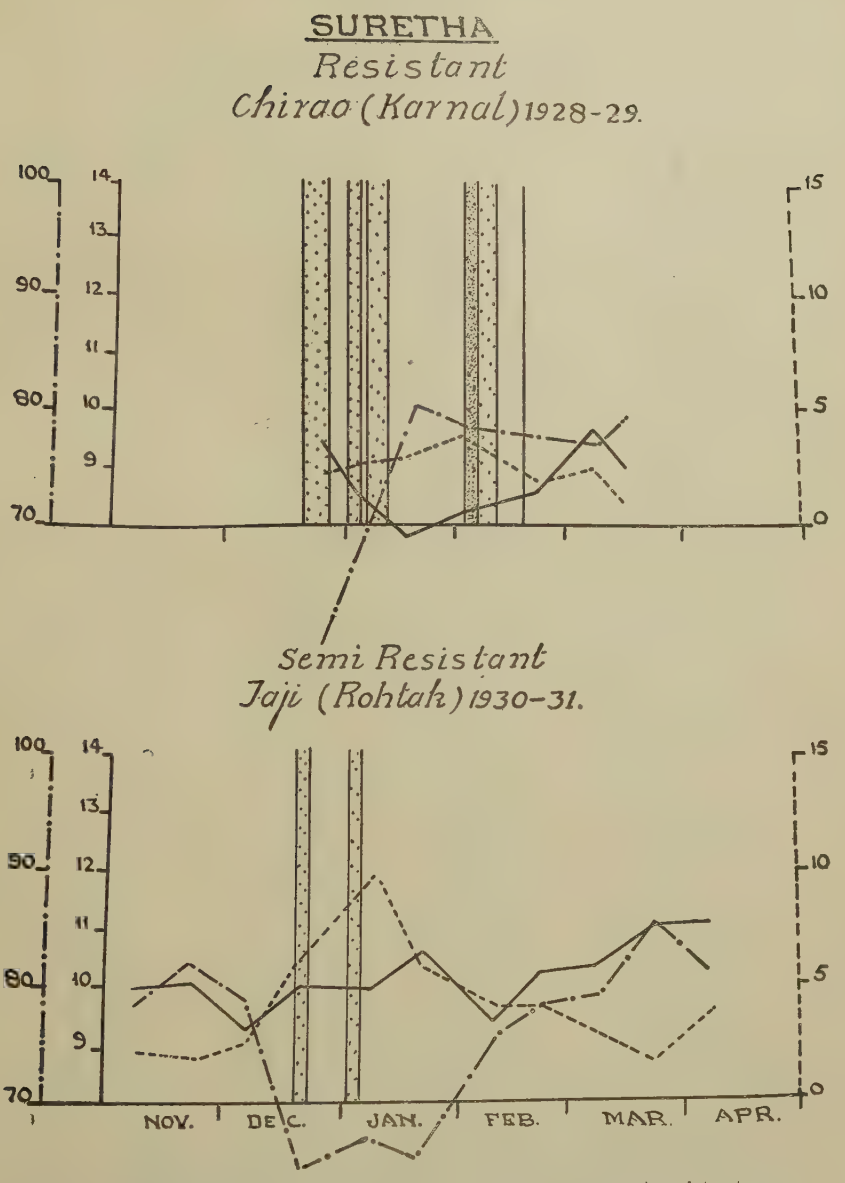


Fig. 4. Response of Suretha to frost as a resistant, and semi-resistant cane

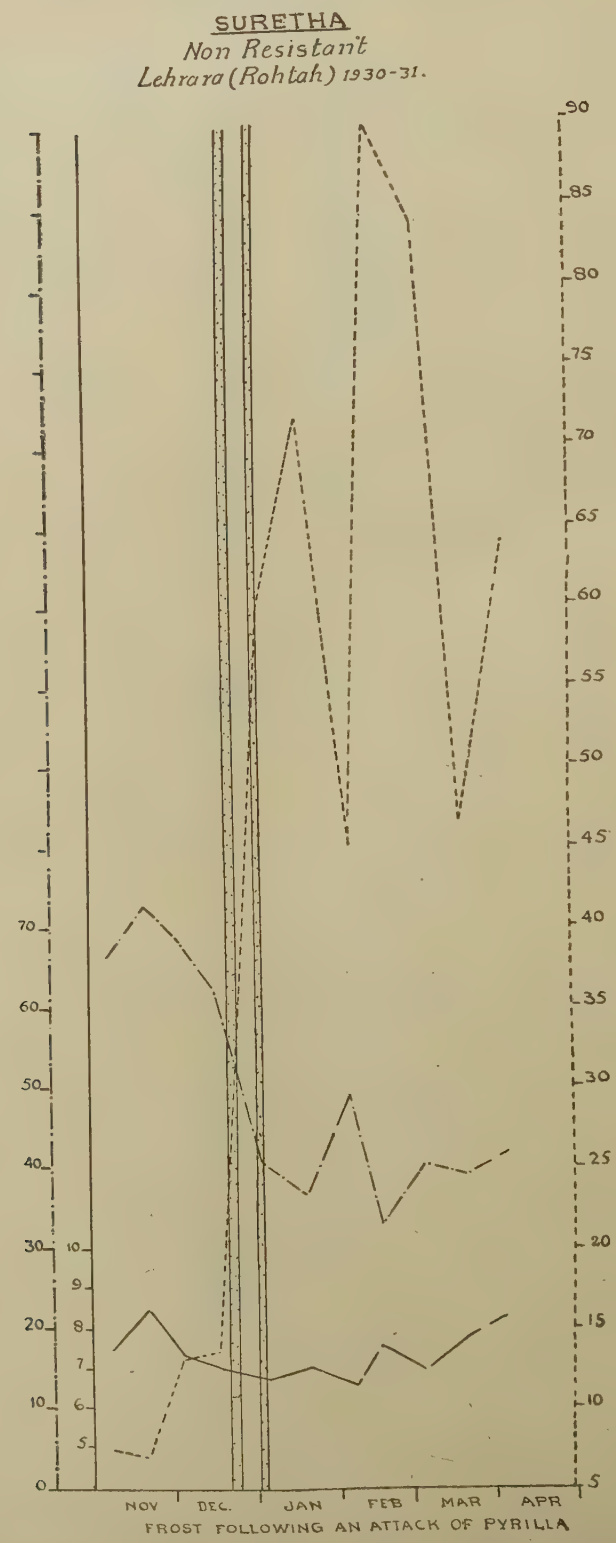


Fig. 5. Non-resistant Suretha, injury by Pyrilla intensified by following frost

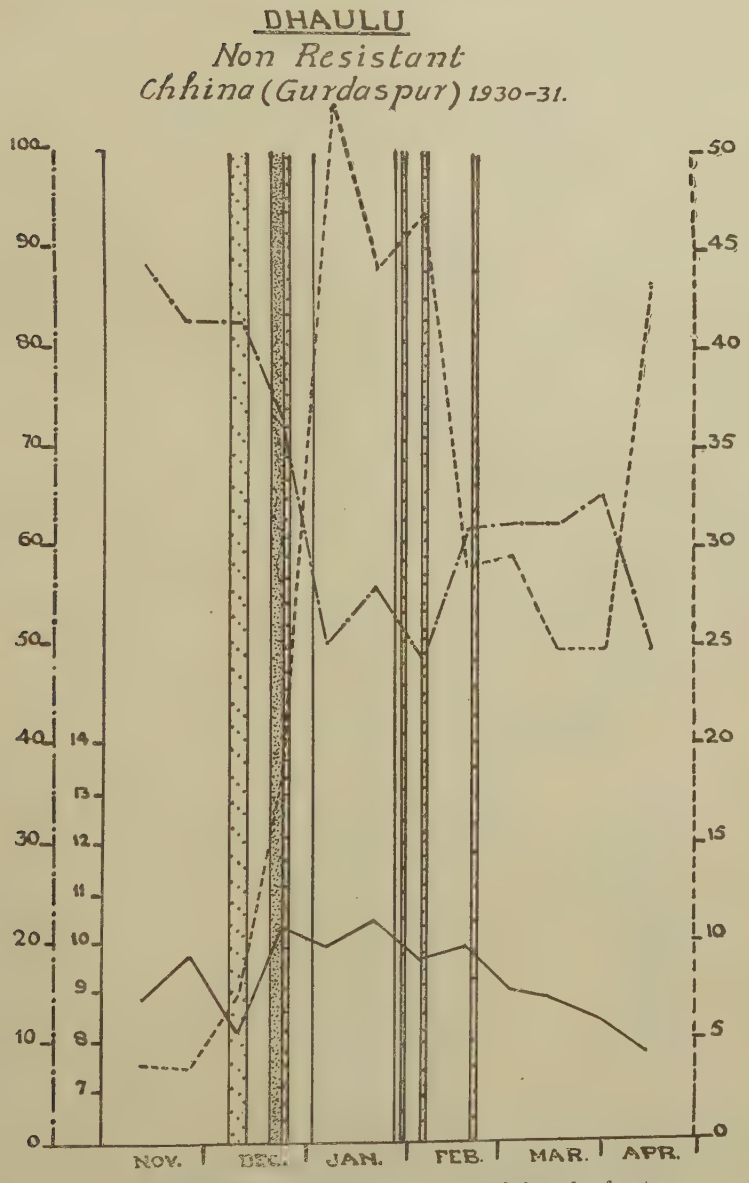


Fig. 6. Great susceptibility of Dhaulu to injury by frost

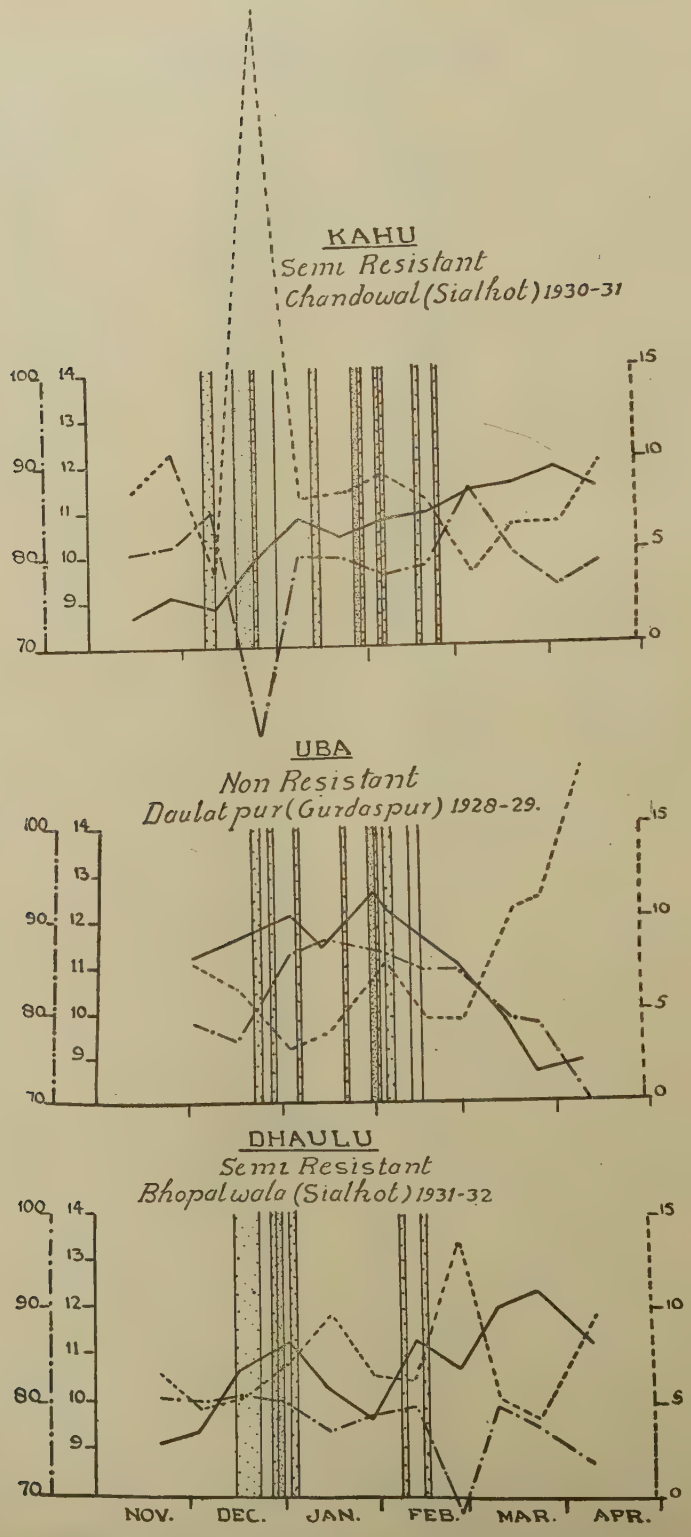


Fig. 7. Response to frost of three indigenous varieties

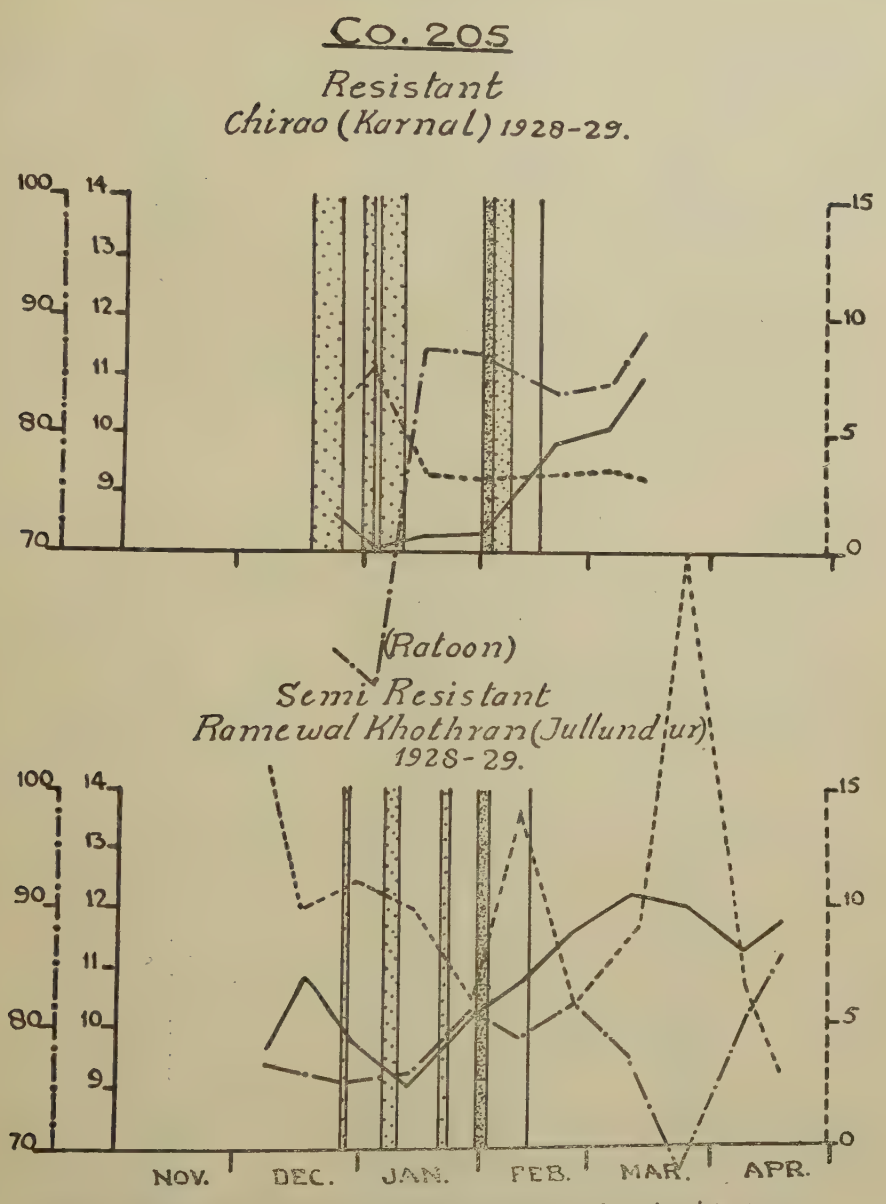


Fig. 8. Response of Co. 205 to frost as a resistant and semi-resistant cane

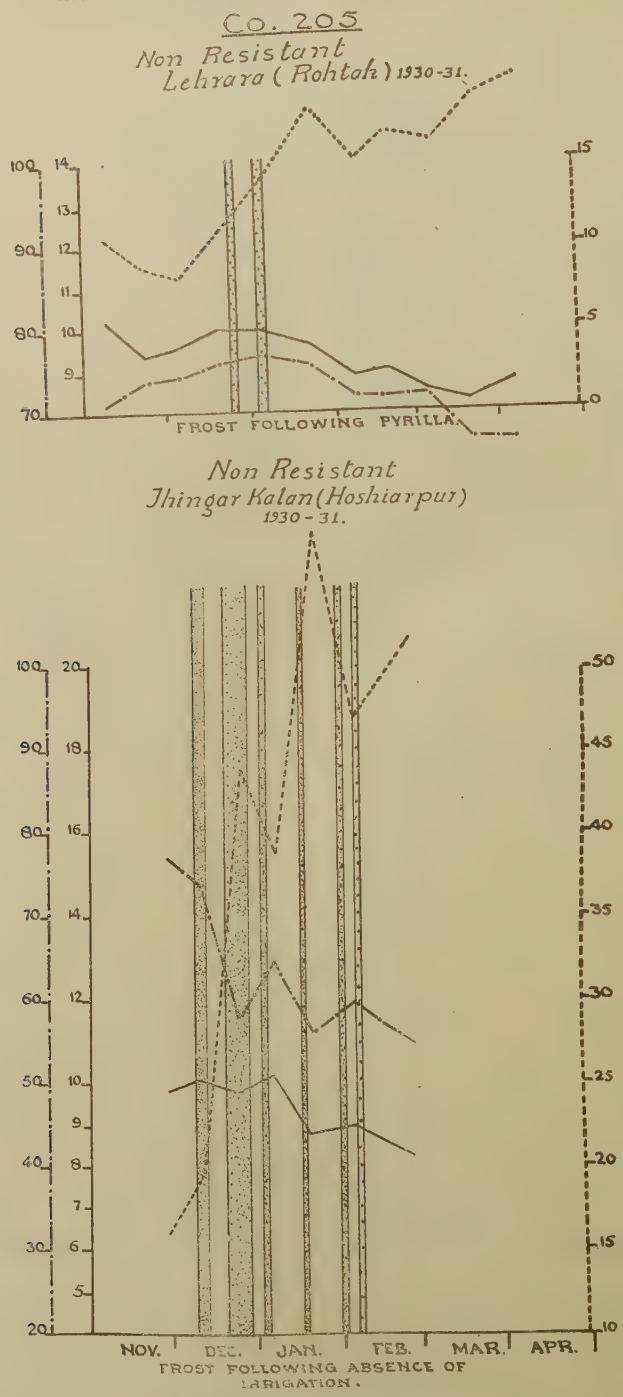


Fig. 9. Injury to Co. 205 due to frost being intensified owing to the abnormal condition of cane before frost

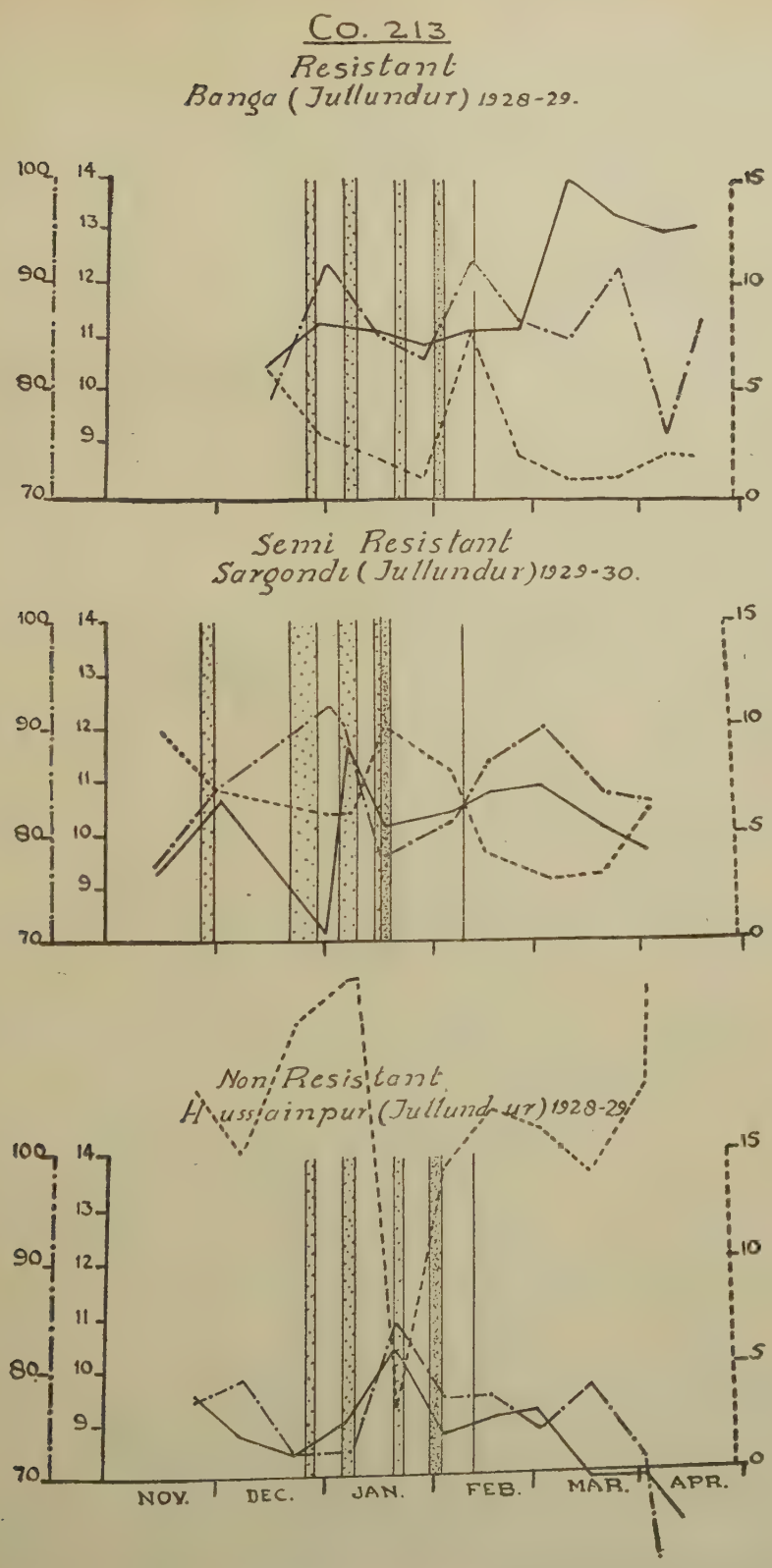


Fig. 10. Response of Co. 213 to frost as a resistant, semi and non-resistant cane

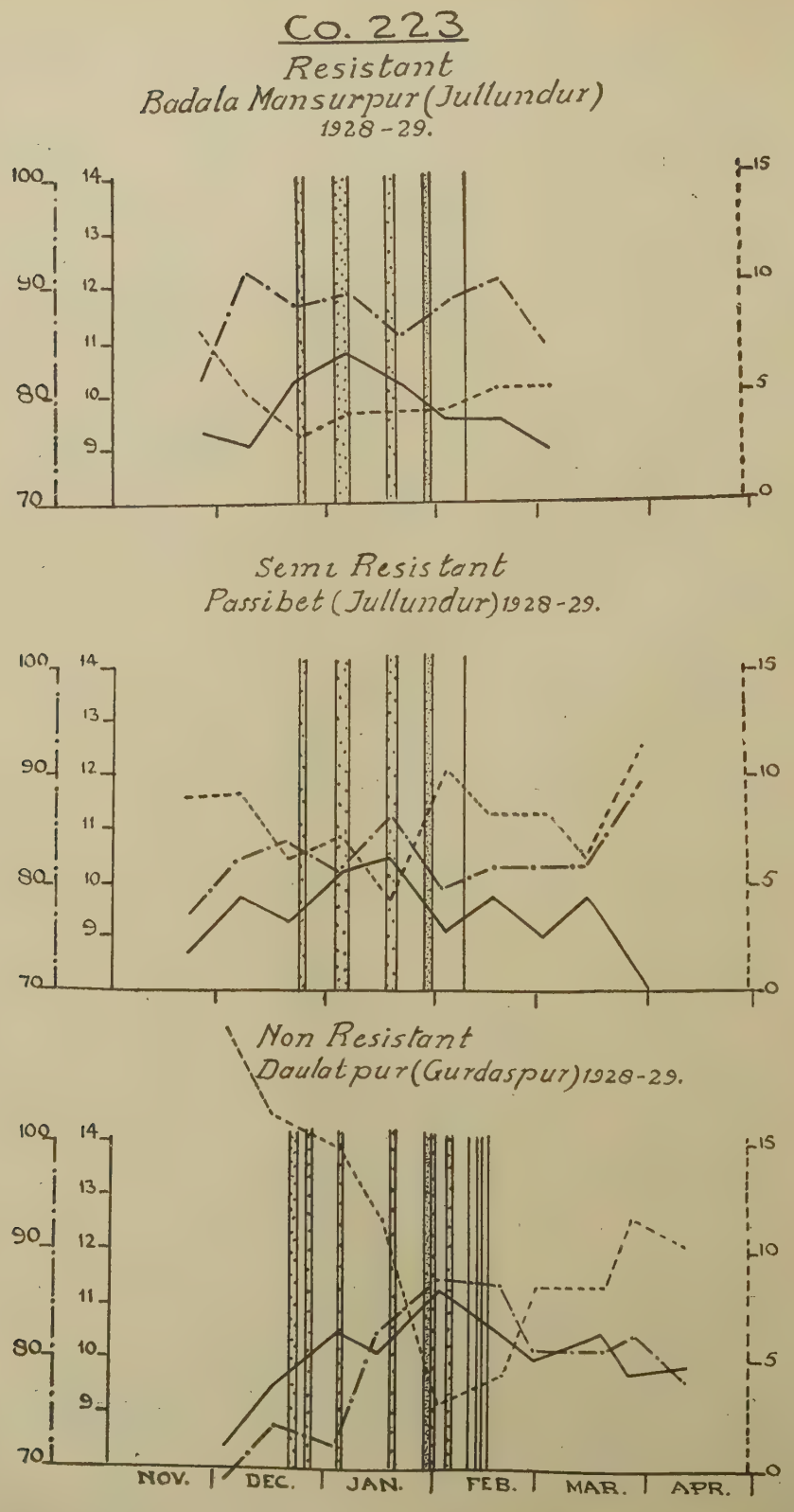


Fig. 11 Response of Co. 223 to frost as a resistant, semi and non-resistant cane

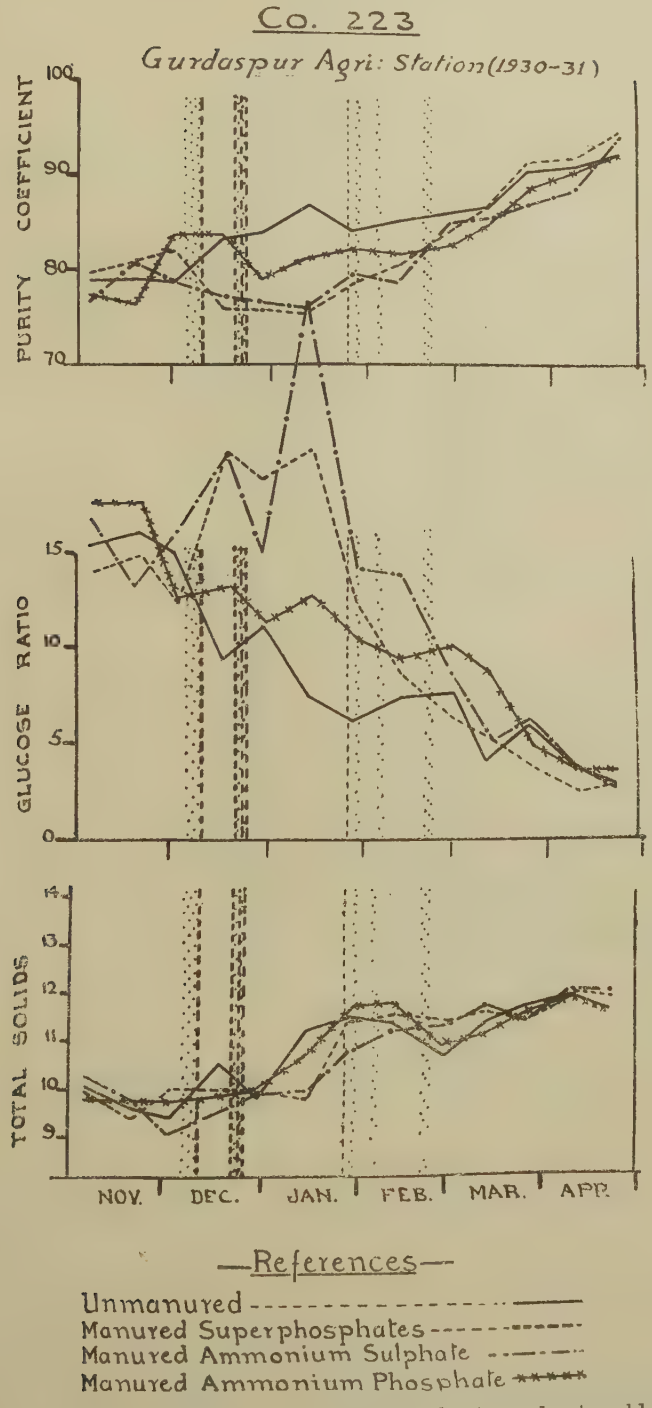


Fig. 12. Delayed maturity, without permanent injury, due to moderate cold following frost

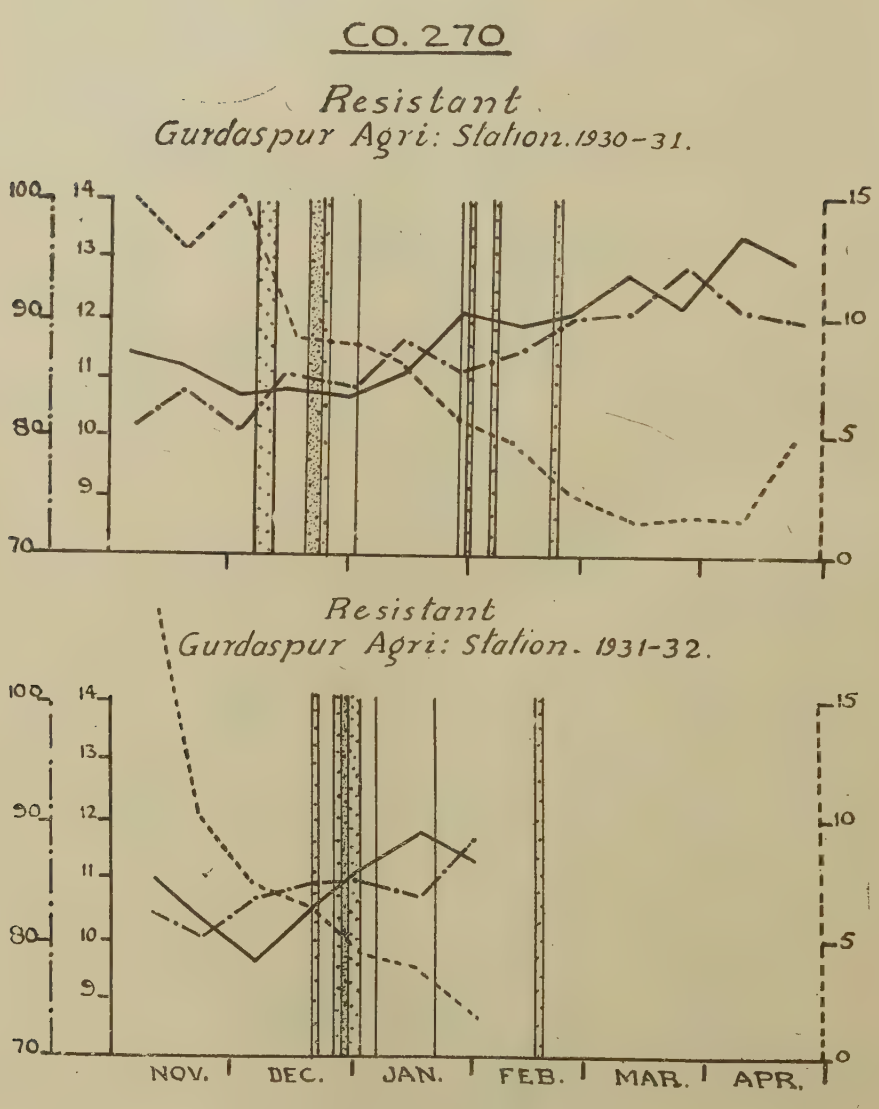


Fig. 13. Immunity of Co. 270 to frost

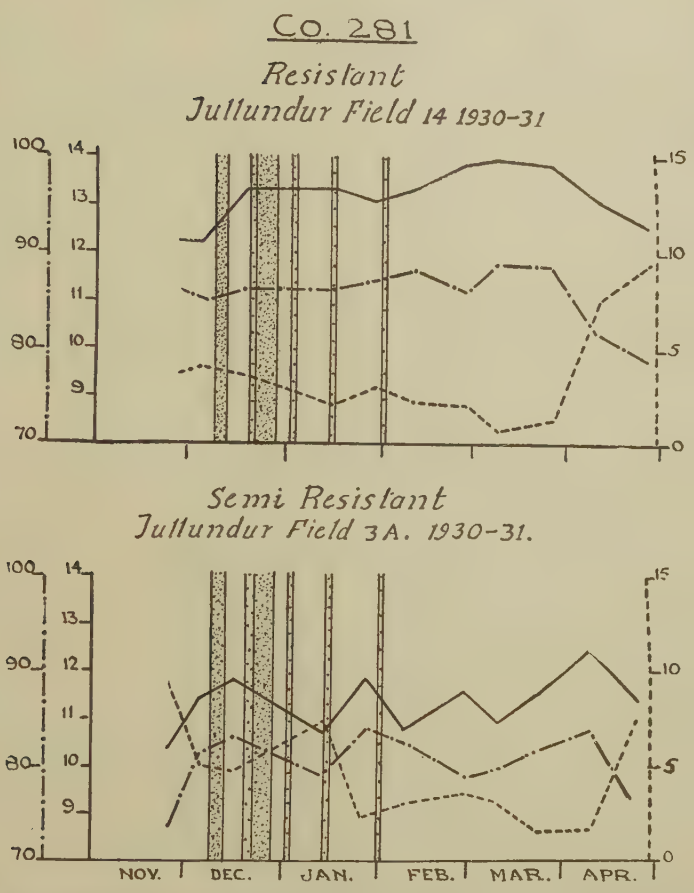


Fig. 14. Response of Co. 281 to frost as a resistant and semi-resistant cane

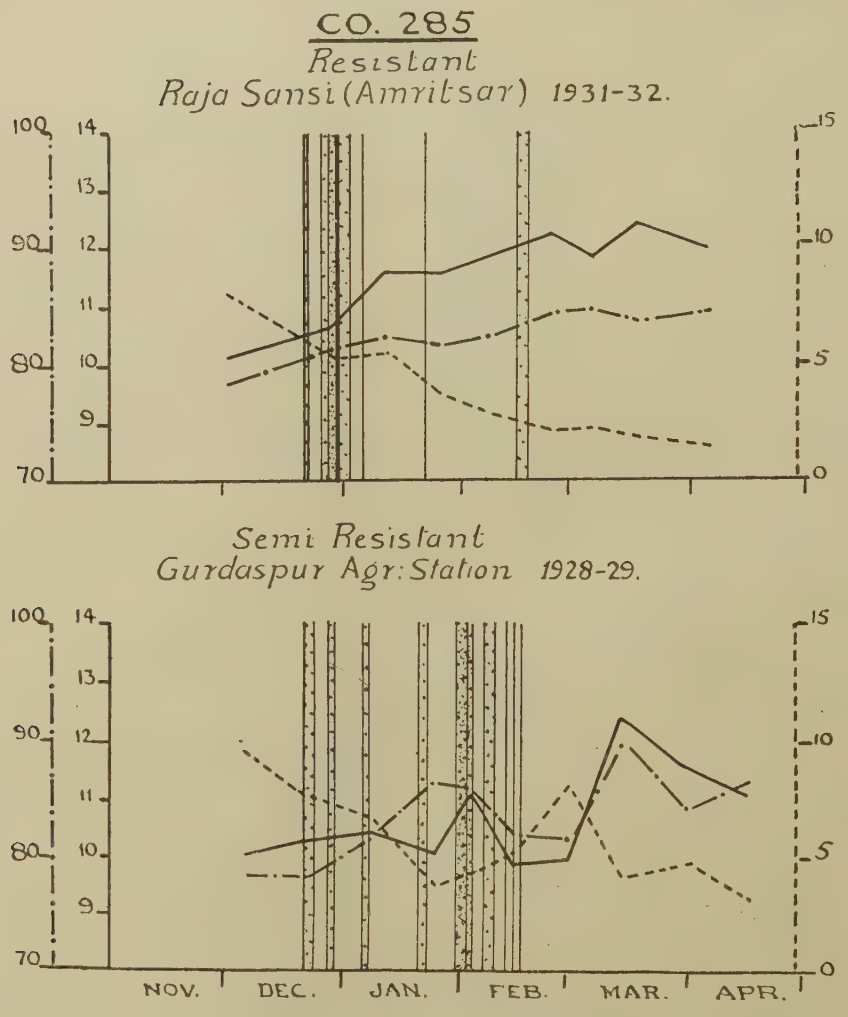


Fig. 15. Response of Co. 285 to frost as a resistant and semi-resistant cane

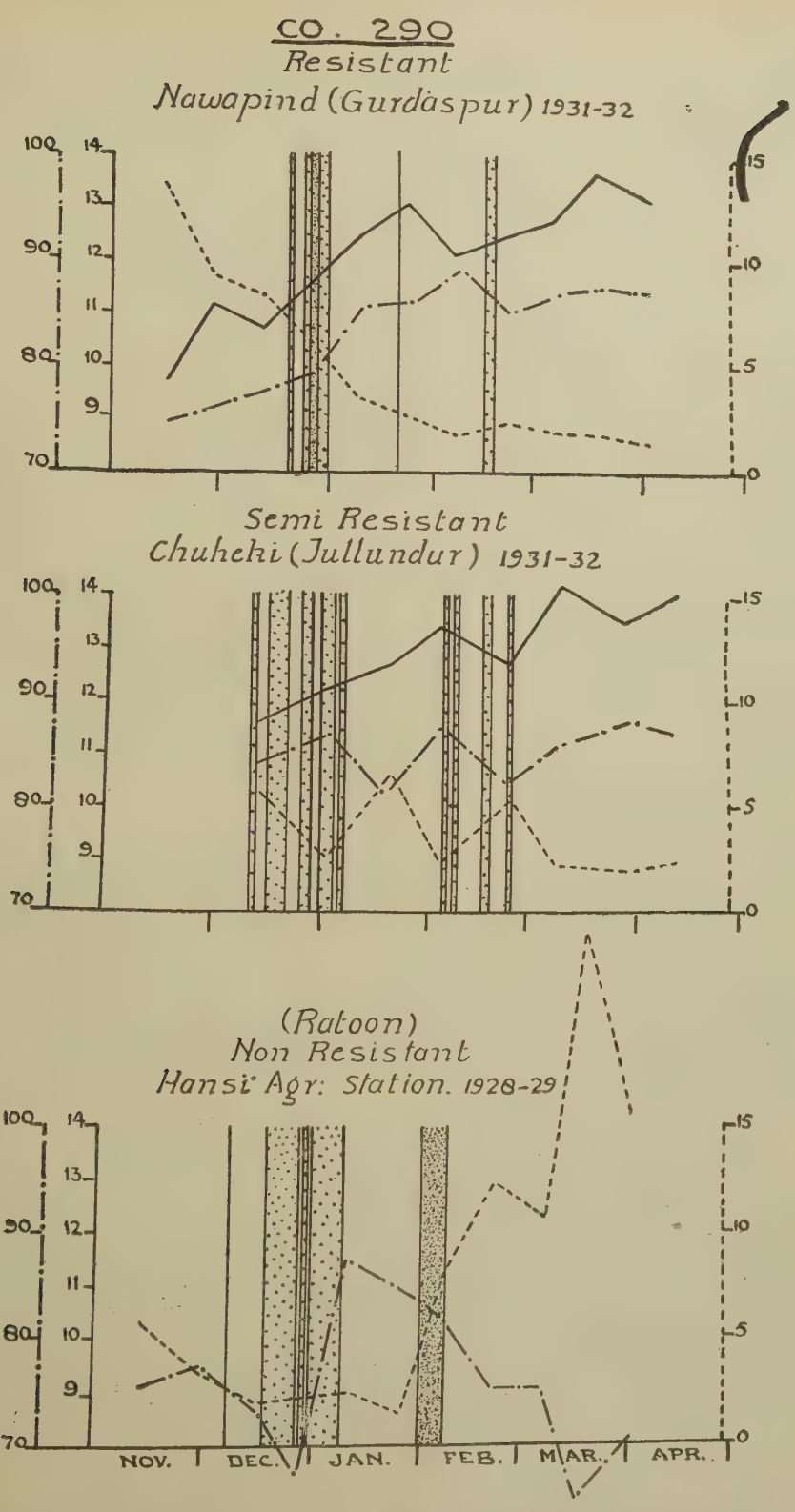


Fig. 16. Response of Co. 290 to frost as a resistant, semi and non-resistant cane

A STATISTICAL EXAMINATION OF THE YIELD OF WHEAT AT THE CAWNPORE AGRICULTURAL COLLEGE FARM, PART I*

BY

R. J. KALAMKAR, B.Sc., B.Ag., Ph.D. (Lond.),

Agricultural Meteorology Branch, Poona,

AND

SRIPAL SINGH, M.A., B.Sc.,

Agricultural College, Cawnpore

(Received for publication on 23rd March 1934)

(With two text figures)

The Cawnpore Agricultural College Farm is one of the earliest research farms started in India and may be expected to provide a useful series of data for statistical examination. The farm is situated in village Gotaiya, about three miles south west of the Cawnpore city. The land occupied was originally rented from the zamindars of Gotaiya in May 1881 and in that year the important manurial experiments whose data are under investigation were started. The soil of the farm may be accepted as a fair sample of the alluvial loam which occurs over a large portion of the Ganges-Jumna Doab.

The original records were brought to Poona for examination. From the vast amount of material a few fairly uniform series of experiments, *viz.*, the "*Kharif* standard series of maize" and the "*Rabi* standard series of wheat" were selected. These experiments had been carried on from 1885-86 to 1913-14 under more or less uniform cultural and manurial treatments. The present investigation deals with the analysis of yields of wheat of the "*Rabi* standard series" in which wheat (Muzzafernagar) was grown year after year. Eight out of the thirteen plots, each 400 square yards in size, are selected for the present investigation as they received a more uniform treatment year after year. The manurial treatments of the selected plots are as given below:—

Plot No. 1.—Saltpetre at the rate of 25 lbs. of nitrogen per acre.

Plot No. 2.—Saltpetre at the rate of 25 lbs. of nitrogen per acre + Bone dust at 10 lbs. of nitrogen per acre.

* The present investigation was made in the Agricultural Meteorology Branch (India Meteorological Department) financed by the Imperial Council of Agricultural Research. The data extends over a period of 29 years. The yields for the two years 1888-89 and 1890-91, were missing but for calculation the means of the yields of preceding and following years were taken for the study.

Plot No. 3.—Cow dung at 100 lbs. of nitrogen per acre.

Plot No. 6.—Sheep dung at 100 lbs. of nitrogen per acre.

Plot No. 7.—Ashes of cow dung containing 100 lbs. of nitrogen per acre.

Plot No. 9.—Saltpetre at 25 lbs. of nitrogen per acre + Bone super-phosphate at 10 lbs. of nitrogen per acre.

Plot No. 11.—Unmanured.

Plot No. 13.—Ashes of cow dung containing 100 lbs. of nitrogen per acre + saltpetre at 25 lbs. of nitrogen per acre.

Prior to 1899, however, the manures had been applied simply by weight without any reference to their actual composition [Leather, 1900]. Cattle dung and sheep dung were applied at the rate of 6·6 tons per acre, the nitrogen supplied by the former being about 75 lbs. and that by the latter about 145 lbs. Saltpetre of second rate quality was applied at the rate of 240 lbs. per acre which supplied on an average about 18 lbs. of nitrogen ; 360 lbs. of bone dust containing from 9 to 12 lbs. of nitrogen were applied ; and bone superphosphate containing on an average about 5 to 6 lbs. of nitrogen was given at the rate of 240 lbs. Since 1899 however the treatments are as noted against each plot.

The object of the present paper is to study the variation in yield from year to year on the above-mentioned eight plots, and to examine the relationship, if any between manurial treatments, mean yields and the variability of the yields. The influence of rainfall on wheat will be discussed in a later paper.

Method of analysis

The yield data for a series of years may be expressed as a polynomial function of time to examine whether there is any secular trend in the yield. The equation may then be represented thus :—

$$Y = a + bt + ct^2 + dt^3 + \ldots\ldots kt^r ,$$

where Y is the calculated yield and t represents the time. The values of yield calculated by this equation represent the general course of its changes due to factors which change in the sense as time progresses. The secular trend being thus allowed for, the deviations of the actual yields from the calculated may be ascribed primarily to the direct and indirect effects of the meteorological elements on the yield of the crop.

The above expression, however, is inconvenient as the values of the coefficients a, b, c, etc., change according as fewer or more terms of the series are used. Fisher [1921] has developed a polynomial method in which the coefficients obtained are independent of the number of terms employed.

The method developed by Fisher [1921] is used in this investigation. It consists in fitting polynomials to the various series of plot yields and analysing the total variation into the contribution due to (a) the average rate of deterioration of

soil due to the exhaustion of natural supplies of food ingredients or to the physical changes, (*b*) slow progressive changes which are of a complex nature and (*c*) annual variation which may be attributed to the direct and indirect effects of the weather elements on the yield of crops.

The fifth degree polynomial is fitted to the series of the wheat plots. The smooth curves are drawn to show the actual course and extent of the slow changes in the mean yield occurring in the differently treated plots. For the arithmetical procedure Fisher's paper entitled " The influence of rainfall on the yield of wheat at Rothamsted " [Fisher, 1924] may be referred to. Precisely the same notation is used throughout the paper. The secular changes in the yields of differently treated plots are given in Table I. The measures x'_2 to x'_6 of the components of change of the 1st to the 5th degree are used since they are directly comparable with the standard residue.

Variability and its causes

As observed above, the variation in the yield is analysed into three parts (*a*) deterioration, (*b*) slow changes and (*c*) annual variation. The deterioration is represented by a linear function although theoretically it is probably more truly represented by an exponential curve, for, the rate of deterioration is expected to decrease as the capacity of the soil to produce as heavy a crop as previously is reduced, due to the depletion of the reserve supplies of plant nutrients in the soil.

Table I

Secular changes in the series examined

	Plot 1	Plot 2	Plot 3	Plot 6	Plot 7	Plot 9	Plot 11	Plot 13
x'_2 . .	—619·92	—133·99	216·53	215·11	—26·77	273·10	—311·75	—158·40
x'_3 . .	—1004·38	—1216·48	—1612·80	—1911·65	—1107·92	—2063·61	—1034·94	—1230·73
x'_4 . .	213·06	—370·63	36·19	215·39	1037·78	294·64	247·89	406·19
x'_5 . .	998·72	924·19	671·09	607·17	1274·86	951·84	866·90	479·30
x'_6 . .	53·92	—264·82	—346·27	—259·14	473·60	327·63	664·25	637·85
S. D. .	347·0	377·1	491.0	565·2	438·3	439·5	452·7	404·9

The total sum of squares of deviations in the yields for the 29 years with 28 degrees of freedom is split up into (*a*) sum of squares of deviations due to deterioration with one degree of freedom (*b*) sum of squares due to slow changes other than deterioration with 4 degrees of freedom and (*c*) the remaining sum of squares with 23 degrees of freedom due to annual causes.

The sum of squares with 23 degrees of freedom serves as a basis to test the significance of the deterioration or slow changes occurring in various plots. The results are given in Table II.

TABLE II

Analysis of variance

	Due to	D. F.	Mean square
Plot 1	Deterioration	1	384301
	Slow changes	4	513633
	Residual	23	120410
	Total	28	186009
Plot 2	Deterioration	1	17953
	Slow changes	4	635366
	Residual	23	142222
	Total	28	208233
Plot 3	Deterioration	1	46886
	Slow changes	4	792675
	Residual	23	241081
	Total	28	312945
Plot 6	Deterioration	1	46273
	Slow changes	4	1034155
	Residual	23	319380
	Total	28	411737
Plot 7	Deterioration	1	716
	Slow changes	4	1038514
	Residual	23	192072
	Total	28	306158
Plot 9	Deterioration	1	74587
	Slow changes	4	1339661
	Residual	23	193183
	Total	28	352730
Plot 11	Deterioration	1	97186
	Slow changes	4	581329
	Residual	23	204909
	Total	28	254836

TABLE II—*contd.*

	Due to	D. F.	Mean square
Plot 13 .	Deterioration	1	25092
	Slow changes	4	579068
	Residual	23	163920
	Total .	28	218269

Deterioration.—It will be observed from Table II that the mean square due to deterioration as represented by the linear term is on all plots smaller than the mean square due to the residual except on plot 1 which receives sodium nitrate. Even here the deterioration is insignificant. According to Fisher's table of 'z' [Fisher, 1931] for $n_1=1$ and $n_2=23$ the 5 per cent value of z is ·7269 which shows that the ratio of the mean square due to deterioration to the mean square due to residual should be of the order of 4·28, and here it is only 3·20 . The analysis therefore indicates that the deterioration as indicated by the linear term is insignificant on all the plots studied. It may be interesting to observe that the plots 3, 6 and 9, as indicated by the signs of x'_2 in Table I, show on the whole an upward tendency instead of diminution in the yield, although the effect is not significant in the light of the standard error.

Slow changes.—In Table I are given the values of x'_2, $x'_3 \ldots x'_6$, the five transformed co-ordinates with their standard error for all the plots studied. These co-ordinates give us the true estimates of the significant slow changes, if any, in the yields of wheat for the different plots studied. Slow changes in the series are exhibited by high positive or negative values in x'_2, x'_3, etc. The slow change due to deterioration as represented by the linear term x'_2 has already been considered. It is found to be insignificant on all the plots although on plot 1 it is comparatively high.

Slow changes other than deterioration are exhibited by x'_3, x'_4, x'_5 and x'_6 by their high positive or negative values. It will be observed from Table I that the values of x'_3 are negative and significantly higher for all the plots as judged in the light of their standard errors. For some plots some of the higher terms also are significant. Contribution to the total sum of squares made by x'_3, x'_4, x'_5 and x'_6 as due to the slow changes other than deterioration are given in Table II. According to Fisher's Table of 'z' [Fisher, 1931] for $n_1=4$ and $n_2=23$ the 5 and 1 per cent values of z are ·5140 and ·7251 respectively, indicating that the ratio of the mean square due to the slow changes to the mean square due to residual should be of the order of 2·8 and 4·3 for 5 and 1 per cent point respectively. It may be observed that the mean square due to the slow changes with 4 degrees of freedom

are significantly higher on all plots compared to the residual variance, particularly on those receiving sodium nitrate alone or in combination with phosphatic manure and also on the plots receiving ashes of cow dung alone.

The course and extent of the slow changes in the mean yield for the eight plots studied are given in Fig. 1. The proportionality of the slow changes is well brought out by plotting the yield figures on a logarithmic scale. All the curves in general show a very close similarity. There is a rise in the yield of wheat up to about 1900 after which period the yields decline. Some of the curves at their end points however show some dissimilarity. The rate of fall of yield is much slower on plots receiving sheep or cow dung, while the unmanured plot and plot receiving cow dung ashes show very rapid fall in yield. Other plots are intermediate.

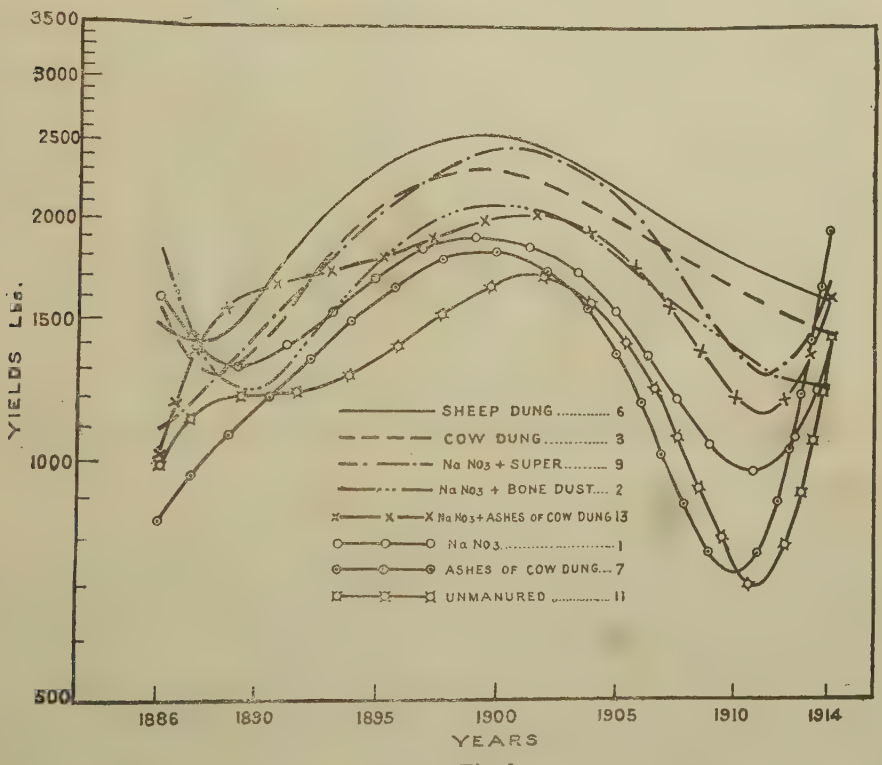


Fig. 1

It is difficult to assign authentic reasons to the slow changes that have taken place on all the plots. Records of the experiments do not contain any special notes such as changes in the type of cultivation,* radical changes in manuring both qualitatively and quantitatively, foulness of the plots due to weeds or surface erosion, etc., which are likely to throw some light on the causes of these changes.

* After submitting the paper one of the authors happened to read the remark made by Howard in his book "Wheat in India" that the marked increase in yield since 1895-96 is due to the deeper tillage and sub-soiling undertaken in that season than that formerly adopted.

Annual variation.—The annual variation for the differently treated plots are shown in Fig. 2. It is expressed on a relative basis. Deterioration and slow changes are also shown in this figure for ease and convenience in comparing them with the differently treated plots. The total sum of squares for each of the three types of variations is divided by the square of the mean yield for the respective plots and these figures are finally expressed as percentage. It may be observed from the diagram that the annual variation is most on plots Nos. 7 and 11, which were untreated for nitrogen.

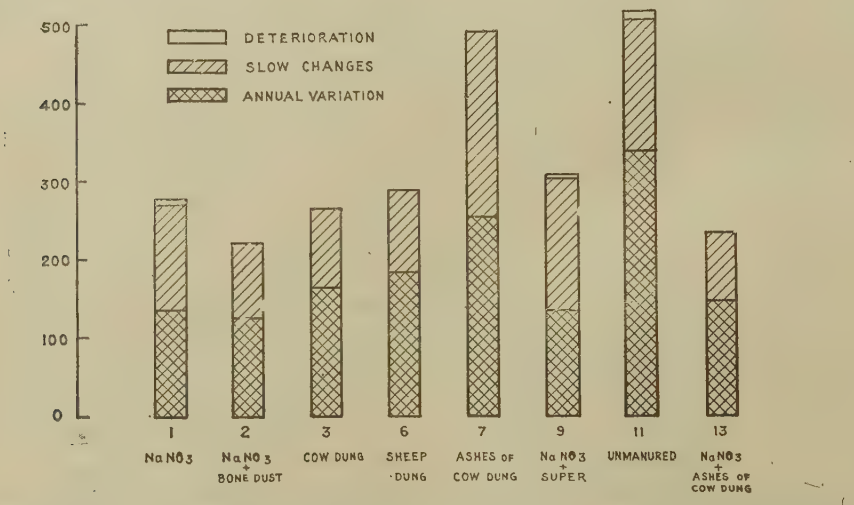


FIG. 2. CAUSES OF VARIABILITY IN THE YIELD OF WHEAT ON DIFFERENTLY TREATED PLOTS.

Yield in relatio to manurial treatment

In the bulletin entitled " Experiments on the growth of wheat and maize at the Cawnpore Experimental Farm " [Leather, 1900], published in 1900, Dr. Leather has discussed data from 1883-84 to 1898-99. He has discussed in detail the effects of manures and fertilisers applied singly or in combinations and has compared the effects with the results obtained at Rothamsted and Woburn in England. The data now examined extend up to 1913-14 and confirm the conclusions arrived at by Dr. Leather in 1900 and further reveals the importance of the applications of phosphatic manures in combination with saltpetre which was not brought out by the earlier investigation.

Table III gives the mean yield of wheat with the standard deviation for each of the plots. The standard deviation is calculated from the sum of squares due to annual variation. The mean annual diminution or increment B, together with the standard deviation for the different plots is also attached. It may be indicated that they are obtained from the values of x'_2 given in Table I by multiplying by a constant, the relation being :

$$x'^2_2 = \frac{n\,(n^2-1)}{12}\,B^2,$$

where n is the number of years over which the data extend.

TABLE III

Plot	Mean yield	S. D.	Coefficient of variation	Mean annual decrement or increment, B	S. D. of B	Mean annual decrement or increment per cent	S. D. per cent.
1	1475·8	347·0	23·5	—13·76	7·70	—·93	·52
2	1631·1	377·1	23·1	—2·97	8·37	—·18	·51
3	1821·7	491·0	27·0	+4·81	10·90	+·26	·60
6	2005·7	565·2	28·2	+4·77	12·54	+·24	·63
7	1330·6	438·3	32·9	—0·59	9·73	—·05	·73
9	1805·3	439·5	24·3	+6·06	9·75	+·34	·54
11	1261·5	452·7	35·9	—6·92	10·05	—·55	·80
13	1634·3	404·9	24·8	—3·51	8·99	—·21	·55

The table shows that plot No. 6, receiving sheep dung, has given the highest yield. The sheep dung supplied contained on an average about 100 lbs. of nitrogen per acre. Plot No. 3, receiving cow dung containing an equivalent amount of nitrogen comes next. But an interesting point revealed by the table is that it is possible to obtain high yields by the aid of fertilisers containing no organic matter provided the fertiliser mixture is well balanced in respect of the food ingredients *e.g.*, plot 9 receiving saltpetre and super gave practically similar yield to plots 3 and 6 receiving sheep dung and cow dung respectively.

Another interesting point is that plot No. 1 receiving sodium nitrate alone does not give significantly higher yield than that of the unmanured plot No. 11. When however, sodium nitrate is applied in combination with phosphatic manures it

increases the yield. Superphosphate seems to be definitely better than bone dust. Plot No. 7 receiving ashes of cow dung gives slightly higher yield than the unmanured plot No. 11. Ashes of cow dung in combination with nitrogenous fertiliser increases the yield (plot No. 13).

We are grateful to Principal C. Maya Das, College of Agriculture, Cawnpore, for making the necessary data available and for the deputation of one of us to the Agricultural Meteorology Branch, India Meteorological Department, Poona.

The authors are also thankful to Dr. L. A. Ramdas, the Agricultural Meteorologist, for his help in the preparation of this paper.

REFERENCES

Leather, J. W. (1900). *Dept. Land Records and Agric., N. W. Province and Oudh, Bull. No.* **9.**

Fisher, R. A. (1921). *J. Agric. Sci.* **11**, 107.

Fisher, R. A. (1924). *Philos. Trans.* **B213**, 89.

Fisher, R. A. (1931). "Statistical Methods for Research Workers" Oliver and Boyd, Edition 4.

SOME OBSERVATIONS ON THE SEED-SETTING IN A TYPE OF TOBACCO

BY

KASHI RAM,

Offg. Superintendent, Botanical Sub-Station, Karnal

(Received for publication on 29th October 1934)

(With plates XVI and XVII)

In 1929, while studying some of the pure lines of tobacco (*Nicotiana tabacum* L.) in the Botanical Section at Pusa it was observed that though Type 56 produced a large inflorescence with numerous flowers during December and January most of the flowers dropped without setting any seed.

Towards the close of the life of the plant, however, some capsules containing normal seeds were formed. In January 1930 the stigmas of certain flowers were observed to be surrounded with scanty pollen and on the next day when the flowers opened they became dark brown and the flowers dropped. Many of the anthers were dark brown when dehiscing and were observed to contain only a very small quantity of healthy pollen. When examined under the microscope, the pollen grains were found to be somewhat irregular in shape but some of them were healthy and sent out pollen tubes when germinated in 3 per cent sugar solution.

In order to obtain definite information about this peculiar behaviour of Type 56, it was sown along with Type 63 as control, late in August and transplanted early in October 1930. A number of flowers opening at different times were marked and the number that formed capsules was noted.

The results are set out in Table I.

TABLE I

Interval of time	Type 56			Type 63		
	No. of flowers marked	No. of capsules formed	Percentage setting	No. of flowers marked	No. of capsules formed	Percentage setting
22nd Dec. 1930 to 23rd Jan. 1931	96	34	35·4	106	101	95·3
24th Jan. 1931 to 12th Feb. 1931	80	42	52·5	64	62	96·9
13th Feb. 1931 to 28th Feb. 1931	96	85	88·5	50	49	98·0
1st March 1931 to 14th March 1931	75	64	85·3	35	33	94·3

From Table I it is clear that there was much flower shedding in Type 56 during December and January (Plate XVI), but with the lengthening of day light and the relative rise in temperature during February and March there was fairly good setting (Plate XVII).

In order to know whether the ovary was receptive during December and January a number of flowers of Type 56 were pollinated with pollen from Type 63 which does not show any lack of setting in the cold season. A good set of seed was obtained as the following figures show :—

Cross	Date of pollination	No. of flowers pollinated	No. of capsules set	Percentage setting
T. 56×T. 63 . .	1st Dec. 1930 .	9	8	89
T. 56×T. 63 . .	28th Jan. 1931 .	8	6	75

This suggests that there is some defect in the pollen of Type 56 during cold season with short day light. To make a positive test of this, crosses were made using Type 63 as the female parent and Type 56 as the male parent with the results shown below :—

Cross	Date of pollination	No. of flowers pollinated	No. of capsules set	Percentage setting
T. 63×T. 56 . .	1st Dec. 1930 .	12	7	48
T. 63×T. 56 . .	28th Jan. 1931 .	7	3	43

From the figures given above it is clear that the pollen of Type 56 did not function properly, giving a lower percentage of setting than in the reciprocal cross. In order to confirm this observation the experiment was repeated again in 1933 on a more extensive scale. Type 56 along with the control Type 63 was grown and transplanted at different times of the season. A large number of flowers in both the types was marked and selfed. The development of a pinkish tinge on the flower bud is generally an indication that the flower will open next morning; hence in selfing care was taken to gum all such flower buds by applying ordinary rubber solution to their apices, the evening previous to the actual opening of the buds.

Type 56, flowering from 22nd December 1930 to 23rd January 1931
(Poor setting of seeds).

Type 56, flowering from 1st March 1931 to 14th March 1931
(Good setting of seeds).

The number of flowers thus marked or selfed and the number of capsules formed were recorded and these are given in Table II.

TABLE II

Period	Mean maximum temperature	Mean minimum temperature	Type 56			Type 63		
			Number of flowers marked	Number of capsules formed	Percentage setting	Number of flowers marked	Number of capsules formed	Percentage setting
A.* 24th Jan. 1934 to 12th Feb. 1934	72·6	48·0	542	86	15·9	141	135	95·7
13th Feb. 1934 to 28th Feb. 1934	78·3	58 3	1713	682	39·8	495	457	92·3
1st March 1934 to 14th March 1934	84·6	57·9	1509	1152	76·3	533	493	92·5
15th March 1934 to 2nd April 1934.	92·7	61·5	Plants damaged later in the season.					
B. 24th Jan. 1934 to 12th Feb. 1934	72·6	48·0	69	12	17·4	29	27	93·1
13th Feb. 1934 to 28th Feb. 1934	78·3	58·3	843	289	34·3	427	397	92·9
1st March 1934 to 14th March 1934	84·6	57·9	1128	926	82·1	719	665	92·5
15th March 1934 to 2nd April 1934	92·7	61·5	1641	1469	89·5	591	565	95·6
C. 13th Feb. 1934 to 28th Feb. 1934	78·3	58.3	437	160	36·6	12	11	91·7
1st March 1934 to 14th March 1934	84·6	57·9	836	697	83·4	226	204	90·3
15th March 1934 to 2nd April 1934	92·7	61·5	951	872	91·7	437	420	96·1
D. 13th Feb. 1934 to 28th Feb. 1934	78·3	58·3	66	23	34·8	3	3	100·0
1st March 1934 to 14th March 1934	84·6	57·9	599	491	82·0	192	178	92·7
15th March 1934 to 2nd April 1934	92·7	61·5	1032	910	88·2	468	435	92·9

A reference to Table II brings out the fact that in the reproductive activity of Type 56 there is some cause which interferes with the normal functioning of the pollen in fertilizing the ovary during short duration of day light and at low temperatures prevailing in December and January so that seed formation is greatly limited.

SUMMARY

In Pusa Type 56 tobacco few capsules are formed during the cold weather with short day light prevailing in December and January but the number increases as the day light brightens and the temperature rises in the succeeding months.

Observations on reciprocal crosses between this type and Type 63 which shows good setting throughout the season indicate that the cause lies in the defective functioning of the pollen of Type 56 during short duration of day light and at low temperatures.

* The seeds were sown in four lots, designated A, B, C and D, at intervals of about a fortnight.

ABSTRACT

Agricultural Turkey. 581. 9 (47). 63 (47). P. Zhukovsky. (*Lenin. Acad. Agric. Sci., Inst. Pl. Ind. Moscow and Leningrad* 1933 Pp. xxvii+908; 381 figs., 12 pls.) (Full summary prepared by the Imperial Bureau of Plant Genetics, Cambridge)

(Reprinted with the kind permission of the Imperial Bureau of Plant Genetics, School of Agriculture, Cambridge, England)

This large tome, comprising some 800 pages of original text represents the fruits of three Soviet expeditions, headed by the author, to Asia Minor. The expeditions have been the means of accumulating a vast amount of plant material, much of it new a d of extreme value, some for immediate introduction, some for breeding.

The general characteristics of the country and its climate are described, followed by chapters on the natural and agricultural flora of the principal zones and the agriculture of the region in general.

In the second section, comprising the main body of the work, detailed descriptions are given of the forms and varieties collected in each individual crop, constituting an invaluable contribution to the Soviet fund of initial breeding material. Particular interest is attached to the discovery of spring forms of *Triticum durum*, among which appear some extremely early varieties, others tolerant of high temperatures, *Fusarium* and frit-fly; barleys have been found with unusually large grain and high yielding capacity and with high protein content; poppies with record earliness, opium content and drought resistance; greatly superior forms of aniseed; melons excelling any in the world in sweetness, juiciness, thickness of the flesh and transportability; cold. resistant winter oats, *Avena byzantina*; sesame resistant to *Fusarium*; flax capable of yielding both fibre and oil; *Phaseolus* immune to anthracnose; and a great abundance of forms of rye and a number of other crops, in some character or other superior to the ones previously known.

The investigations have succeeded in demonstrating that Anatolia is the centre of origin of many of the best European cultivated plants. The cultivated type of soft wheat, the squarehead type in particular, apparently originated in Anatolia and penetrated into Europe later; the same is true of the cultivated forms of the European leguminous plants, the best forms of sesame, the table carrot, cultivated aniseed, the cantaloupe and casaba melons, cucumbers, French lucerne, the opium poppy, various fruit trees and wine grapes. Literally thousands of cultivated forms of these several plants have been found. In wheat the greatest variety is found in *T. durum*, including many endemic forms and characters. The well-known Kubanka wheat is present in great variety, indicating that it too has in all probability entered Russia from Anatolia. There are endemic forms and characters also of *T. turgidum* and two species of wild wheat are present in abundance. The country is divided into very varied climatic regions and in consequence the wheats display a wider range of ecological types than those of any other *durum* wheat country; even in Abyssinia, the country of the greatest

botanical diversity, the ecological type is relatively uniform. Some of the new forms of *T. durum* have already been used in crossing on account of their low temperature requirements, tolerance of excessive moisture and immunity to *Fusarium*, all of which characters are required for extending the northern limit of *T. durum* cultivation. The variety *asiaticum*, besides being immune to *Fusarium*, entirely escapes frit-fly attack owing to its earliness, low tillering and vigorous and rapid early growth. The dwarf *T. durum* comes into ear earlier than any other known forms and is hence extremely valuable for certain parts of the U. S. S. R. Hybrids of this are in the third generation. Another valuable breeding character of these wheats is the high quality of their grain, the variety *horanicum* having excellent vitreous grain of spherical shape, maturing very early. Some of them also respond favourably to vernalization.

The botanical variation in the wheats is equally great, especially in the Mediterranean region of Anatolia, which is regarded therefore as an important, though not the primary, centre of origin of the 28-chromosome wheats. The 42-chromosome group shews much less diversity, except *T. compactum*, which may have a secondary centre in Anatolia and Transcaucasia. A new and endemic 42-chromosome species, *T. cavilovi* characterized by branched ears, has been discovered, however, and is here described. The 14-chromosome group of wheats and the genus *Aegilops* have their centre of greatest diversity in Anatolia and the Crimea and two new species of *Aegilops* have been found there.

The barleys of Anatolia are much less varied but nevertheless are of breeding value or their drought resistance, strong straw, non-shattering ears and large elliptical grain which shews considerable variation in protein and starch content.

Rye is found universally, as a weed in all the wheat fields and also as a pure crop. These ryes display a greater diversity of varieties, forms and characters than is found in any other country, in the form and colour of the ear which varies from yellow to black, in the form and colour of the grain, varying from elongated to nearly spherical and from yellow, green and purple to nearly black ; awnless forms appear, forms with smooth, pubescent and warty glumes ; forms with branched ears, others with three grains per spikelet, types with wax and types without, and certain self-pollinating ryes. Many of these forms are new and endemic ; a new wild species, *Secale ancestrale*, has been found in great abundance and in a great variety of forms, as well as the commont wild *S. montanum* and the allied genus *Haynaldia villosa* (*Secale villosum* L. syh. *Triticum villosum*). The extreme heterozygosity of the ryes of this region is thought therefore to be the result of frequent intercrossing between the various forms and species and there is no doubt that this is the centre of origin. *Secale fragile* also occurs but there is evidence that the area of development of the hybrid forms is distinct from that of the original species. *Haynaldia hordeacea* is thought to have possibilities for crossing for producing a perennial rye for the north and for arid zones ; similarly *H. villosa*, *S. ancestrale* and *S. montanum* for producing drought-resistant forms and forms suitable for sandy districts.

Avena byzantina has been grown in Anatolia from ancient times. It is cultivated as a winter crop and is a common weed. It is present in a great variety of forms, some endemic ; it is rich in winter and semi-winter forms which are of great use in certain parts of the U. S. S. R.; and in addition to cold resistance they have large grains with high

content of protein and oil, and are resistant to rust, shattering and lodging ; some are also very early and altogether this is regarded as the most valuable material for oat breeding yet found. There is a great variety also of wild *Avena* and Anatolia is regarded as the centre of origin of a whole group of oat species ; the process of its gradual conversion from a weed to a cultivated plant can be observed at the present time in the wheat fields ; the weed forms contain a much greater wealth of variation than the cultivated forms and many of them are endemic. Natural hybridization is common and the progeny of these natural hybrids often contains further new forms, some of which moreover are extremely similar to Burt and other new hybrids obtained from the U. S. A.

Maize and rice, which are introduced crops, are much more uniform.

Many of the leguminous plants on the other hand display a tremendous variety, *e.g.*, the variation in seed form, vegetative period and morphological characters in the grams (*Cicer arietinum*) mark it as one of the most valuable known sources of breeding material. Anatolia is second only to Persia in richness of species of *Cicer* ; there are five wild and two endemic species, though the supposed wild ancestor of the cultivated gram *C. judaicum* is not present. The examination of the wild species leads to the suggestion that several of them have contributed to the origin of the cultivated forms, possibly partly by hybridization ; this view can only be substantiated by genetic study of the wild species. Anatolia contains a large number of endemic varieties recessive characters being predominant ; the Anatolian grams excel all others in quality and most others also in yield.

Of lentils a considerable range of varieties is found, including the intermediate as well as large and small-seeded varieties of *Lens esculentum* and all the four wild species. In opposition to Barulina's view the author thinks it likely that the large-seeded forms have arisen by hybridization of the original small-seeded form with some of the wild species such as *L. Kotschyana* or *L. orientalis*, leading to the independent origin of lentil cultivation in the Mediterranean, where the different type of cultivation, *e.g.*, winter sowing, made possible the evolution of the forms with larger seeds. The position with regard to beans (*Vicia Faba*) is different, in that the small-seeded forms are much rarer, no endemics are found and the general character of the crop corresponds to that of the Mediterranean countries. They are nevertheless of great practical interest for breeders on account of their large beans, earliness and high quality ; similarly with regard to *Phaseolus*, some of which are resistant to drought and others to anthracnose.

Although Anatolia is the home of all the wild species of *Pisum* hitherto known, *P. sativum* is very little cultivated and the forms cultivated are much less varied than those of Afghanistan and Abyssinia. Two new species have recently been discovered in Georgia and these may shed light on the origin of the cultivated pea ; at present however there is very little relationship between the cultivated and the wild species. The Anatolian group represents a distinct type from the peas of Afghanistan or Abyssinia ; in ecological characters it is very much more varied, including the reaction to reduced length of day, and although there are many isolated characters shewing the influence of Afghanistan, Transcaucasia and the Mediterranean countries it is clear that the peas of Anatolia have for a long time evolved independently.

Vetches on the other hand are present in remarkable abundance and variety, both as wild species growing as weeds and cultivated forms of *Vicia sativa*, the majority of which are endemic. Most of the characters are common to the cultivated and weed forms, the latter being richer in characters and it seems probable that in this region the process of "domestication" is still in progress. The group is in every way distinct from the two sub-species hitherto recognized and is established as a separate sub-species, *turcica*. Among the general characteristics of this group are smallness of plant, extreme earliness, cold resistance, abundant seed production and firm attachment of the seed coat. Earliness and abundant seed production are characteristic of the Anatolian *Lathyrus*, of which two cultivated species *L. sativus* and *L. ochrus* occur.

Special interest is attached to the sesames on account of their great diversity and their high quality. Most of them have white seeds, these varieties being endemic; they are also characterized by high oil content and very pronounced resistance to diseases such as *Fusarium*, bacteria and gumming. Of linseed too there is a whole endemic group, intermediate in character between the Asiatic and Mediterranean groups ; there is a further prostrate form in many ways resembling the wild forms, endemic for Anatolia and Transcaucasia, and capable of withstanding very low temperatures and growing in poor, sandy situations. The high yield of capsules and the large seeds, combined with their high oil content, have directed the attention of breeders to the Anatolian linseeds.

Anatolia is apparently the home of aniseed. *Pimpinella anisum* grows wild in certain parts of the country and there is an unusual variety of cultivated forms. These yield more heavily than the forms of any other country, though in essential oil content they are inferior to the Spanish forms. However, a new species, *P. anisetum*, endemic in eastern Anatolia, has been found remarkable for its high oil content (8·3 per cent as compared with 3·4 per cent for *P. anisum*), its vigorous growth, high yield and pronounced cold resistance. It is a biennial and very resistant also to fungous diseases. Its one defect is that the essential oil it yields is of a somewhat lower quality, containing as it does a smaller proportion of anetol.

Wild growths of oleander, jasmine, rosemary, lavender (*Lavandula Stoechas* L.) and other aromatic plants are also found in abundance.

The local cotton is *Gossypium herbaceum* but adventive species such as *G. hirsutum* and *G. punctatum* are also present, all of distinctly low quality.

A special endemic sub-species of the opium poppy, consisting of several distinct ecotypes, is described. It is regularly accompanied by semi-cultivated types belonging to the dehiscent sub-species, *semispontaneum*, thought to be nearly allied to the wild ancestor of the cultivated poppy. The high morphine percentage and early maturity of the cultivated forms, together with their tolerance of both cold and drought have attracted the attention of Soviet breeders. Their yield of opium is unfortunately low and they are being crossed with Soviet forms having high opium content in the attempt to combine this with their high morphine percentage which in some cases was as high as 28·33 per cent.

A study of the present distribution of the cultivated poppy together with the genetic and cytological investigation of it and of the Mediterranean wild species *Papaver setigerum* have led to the conclusion that this is not the wild ancestor of *P. somniferum*.

The greatest number of forms and characters is found in the Central Asiatic Republics of the Soviet Union, where three endemic sub-species occur and which must therefore be regarded as the scene of origin of the cultivated species. In Turkey also there occur primitive forms with dehiscent capsules, and with warty capsules of the type used for producing edible seeds and the present Anatolian and Persian forms are thought to have evolved later from forms originally coming from Turkestan. The great variety and wide distribution of cultivated poppies of the present day have arisen monophyletically, as the result of man's agency.

Each vilayet has its own peculiar type of melon, resulting from age-long selection independently of neighbouring vilayets. An untold wealth of forms has thus originated. Of these frequently only the most inferior have penetrated into other countries. The true melons constitute an endemic group *gracilior*, some of which are of exceptionally high quality, with a sugar content higher than any known melon, exceeding 9 per cent in some cases. One of the casaba melons found has been pronounced the best melon in the world on account of its combination of sweetness, juiciness, thick flesh and "buttery" consistency. It is to be used in crossing with more aromatic types of melon. The vilayet of Van is famed as the home of the cantaloupes and still contains a great variety of forms, many of which have not hitherto penetrated into Europe, whilst the snake melons also have their centre of diversity in Anatolia. Of water-melons both the cultivated and weed forms exist in great diversity, also as a special group *gracilior* inferior however to the water-melons of Persia and neighbouring countries. Again *Cucurbita Pepo* has a special Anatolian sub-species, *turcica*, representing the greatest variety of forms known in Europe, in addition to which there occur peculiar bushy forms. It is significant that the Anatolian forms of all the various cucurbit species, including the cucumbers, are characterized by the same group of botanical features, *viz.*, that associated with the type *gracilior*. New botanical groups are established within the respective species, each consisting of a number of botanical varieties, all of which are endemic and are described ; each has a clear regional distribution, which is indicated. It is clear that Anatolia is the primary centre of origin of the melons and an important secondary centre for the pumpkins and watermelons. Even the cucumbers which penetrated from India, have to a certain extent evolved and produced a characteristic local type.

As regards the other vegetables great variability was found among the beets, not only in morphological but in biological and ecological characters ; a whole group of orange-coloured beets is endemic in central and eastern Anatolia, a group having exceptional interest as breeding material. Again in the case of carrots, all the characters, and all the forms known to exist in the cultivated carrot are concentrated in Anatolia, both those associated with the Asiatic and with the European groups, both of which are represented ; moreover, a much greater range of variation has been disclosed by this material than was known to exist in the carrot and new possibilities in breeding have been opened up. In addition to typical European and typical Asiatic types, all possible intermediates are found not in respect of one character alone but in respect of all distinguishing characters. Investigation has shewn that the Asiatic carrots are lacking in plastids, the pigment being in the cell sap, whereas the European group owes its colour entirely to the plastids ; hybrids between them contain pigment of both kinds and so also do the intermediate forms occurring in Anatolia. In addition there is an

endemic group distinguished by the very large dimensions of the whole plant and more nearly allied to the wild sub-species *Daucus Carota* subspecies *Maximus*. This new group, named *Adanensis*, also contains purple and yellow forms corresponding to those occurring in the cultivated group. The concentration forms in Anatolia is evidently the result of the overlapping in this area of the two wild sub-species *D. Carota* subspecies *Carota* and *D. Carota* sub-species *Maximus* from whose hybridization the European group of cultivated carrots has evidently arisen. Anatolia is thus regarded as the primary centre of origin of the European group as well as a secondary centre of originl of the cultivated carrot as a whole. Although nearly the whole range of variation of carrots found in Anatolia, with the exception of the endemic Anatolian forms, occurs also in the various countries of the Soviet Union, the Anatolian populations are more regular in form and size of root and are therefore useful for breeding. Some of them contain a valuable essential oil, lemonene, and most have the advantage of being drought-resistant and, finally, their richness in characters makes these carrots an invaluable starting point for genetic studies.

The Anatolian cabbages are characterized by pronounced response to the influence of length of day, to which the European cabbages are more or less neutral. The cabbages of Anatolia are more drought-resistant than any yet known ; they are very susceptible however to *Peronospora brassicae*. In addition to cauliflowers there are specimens of the headless cabbage (var. *acephala*) and hybrids between them showing vegetative segregation. Hybrid forms between *acephala* and the headed cabbage were also found Many of the forms of the cabbage group are of a semi-cultivated type and some are endemic ; the variety of forms of the oriental group is greater than that in neighbouring countries to the west and there are indications that the Anatolian cabbages form an ancient group in the origin of which the Syrian group has participated. They contain many forms and characters of value to Soviet breeders and will be used both in analytical and synthetic breeding.

Quantities of wild olives are found growing even in most unfavourable situations and poor mountain soils. There is also an abundance and variety of figs, of wild species and forms of pears, plums, cherries, almonds, hazels, walnuts, chestnuts, pistachio, the kernel pine, *Rubus*, *Ribes* and *Vaccinium*; and there is an endemic wild species of vine, *Vitis orientalis*. The Smyrna fig, the North Syrian pistachio and certain groups of the cherries, pears, plums and almonds are endemic. All these wild fruits and nuts are used by the inhabitants and often the inferior ones are removed to leave room for the best specimens ; in this way they have come gradually into cultivation, and various degrees of the process are to be seen at the present time.

The peculiar characteristics of the flora of Anatolia are explained when it is realized that this is the only country where the continents of Asia, Africa and Europe meet. It is the meeting place of different types of allied plants, the oriental anthocyanin carrot and the wild carrot, the cultivated and wild vine, the large and small-seeded forms of many leguminous plants, hence intermediate forms or often new types altogether have

resulted. The wide range of ecological conditions in the country and the low degree of purity of the crops have favoured the preservation of the greatest possible number of these new forms. Yet most field and vegetable crops are remarkably uniform as regards the character and quality of the seeds, evidence of a deliberate selection on the part of the agriculturists of the past. All these reasons have contributed to make Anatolia the source of many of the most valued varieties cultivated in Europe.

The volume under review terminates with a bibliography of 27 pages, an index of Turkish, Latin, Russian and geographical names and an extensive French summary It is provided with an excellent map of the country and is unusually well printed and illustrated.

NOTE

SOIL DEFICIENCIES AND PLANT DISEASES: IMPERIAL BUREAU OF SOIL SCIENCE TECHNICAL COMMUNICATION No. 31

Technical Communication No. 31 of the Imperial Bureau of Soil Science, Rothamsted, "Soil Deficiencies and Plant Diseases" deals with the border line of plant physiology and soil chemistry. Dr. Jacks and Miss Scherbatoff have collected and summarised the relevant facts from some hundreds of papers and provided a bibliography of 367. This bulletin does not deal with the phenomena associated with nitrogen, potash or phosphatic starvation, but with the pathological conditions which have been ascribed to deficiencies of the so-called minor elements, notably manganese, iron, magnesium, boron, sulphur, copper and zinc.

A handy table of deficient elements, main crops affected and numerical references to the main bibliography considerably enhance the utility of the bulletin (Ed).

GIPD—M647 IC of AR—10-6-35—800.